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Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Visual Sample Plan Version 5.0 User's Guide

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Prepared for the U.S. Department of Energy
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Abstract

This user's guide describes Visual Sample Plan (VSP) Version 5.0 and provides instructions for using the software. VSP selects the appropriate number and location of environmental samples to ensure that the results of statistical tests performed to provide input to risk decisions have the required confidence and performance. VSP Version 5.0 provides sample-size equations or algorithms needed by specific statistical tests appropriate for specific environmental sampling objectives. It also provides data quality assessment and statistical analysis functions to support evaluation of the data and determine whether the data support decisions regarding sites suspected of contamination. The easy-to-use program is highly visual and graphic. VSP runs on personal computers with Microsoft Windows operating systems (98, NT, 2000, Millennium Edition, CE, and XP). Designed primarily for project managers and users without expertise in statistics, VSP is applicable to two- and three-dimensional populations to be sampled (e.g., rooms and buildings, surface soil, a defined layer of subsurface soil, water bodies, and other similar applications) for studies of environmental quality. VSP is also applicable for designing sampling plans for assessing chem./rad/bio threat and hazard identification within rooms and buildings, and for designing geophysical surveys for UXO identification.

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1.0 Introduction

1.1 What is Visual Sample Plan?

Visual Sample Plan (VSP) is a software tool for selecting the right number and location of environmental samples so that the results of statistical tests performed on the data collected via the sampling plan have the required confidence for decision making. More than 4000 users from every state as well as many in other countries have registered a downloaded copy of VSP. Users include employees of the federal government, state and local governments, and private industry. Sponsors of this public domain software include the U.S. Environmental Protection Agency (EPA), U.S. Department of Energy (DOE), U.S. Department of the Defense (DOD), U.S. Department of Homeland Security (DHS) , National Institute for Occupational Safety and Health (NIOSH) within the Centers for Disease Control and Prevention (CDC), and the U.K. Atomic Weapons Establishment (AWE).

VSP provides sample designs and sample-size equations needed by specific statistical tests appropriate for several types of environmental problems. Table 1.1 is a list of the sampling goals that can be addressed in the current version of VSP.

Table 1.1. List of Sampling Goals

Sampling Goal	User's Guide Section
Compare Average to Fixed Threshold	3.2.1
Compare Average to Reference Average	3.2.2
Estimate the Mean	3.2.3
Construct Confidence Interval on Mean	3.2.4
Compare Proportion to Fixed Threshold	3.2.5
Compare Proportion to Reference Proportion	3.2.6
Estimate the Proportion	3.2.7
Locating a Hot Spot	3.2.8
Find UXO Target Areas	7.1-7.4
Assess degree of confidence in UXO presence	7.5
Non-statistical sampling approach	3.2.11
Establish boundary of contamination	3.2.12
Sampling within Buildings	3.2.13

VSP is easy to use, highly visual, and graphic. It has extensive online help and tutorial guides. Reports produced by VSP can be pasted directly into a quality assurance project plan or a sampling and analysis plan. VSP can be used to implement EPA's systematic planning process (EPA 2000a) for a variety of problems: selection between clearly defined alternatives [Step 7 of the Data Quality Objectives (DQO) process], studies where a confidence interval on an estimated parameter is needed, or determination of whether a hot spot or target exists. The user specifies the criteria for "how good" the answer has to be (Step 6 of the DQO Process), and VSP uses this as input to the formula for calculating the required sample size. VSP is unique in this regard.

VSP is designed primarily for project managers and users who are not statistical experts, although those individuals with statistical expertise also will find the software very useful.

1.2 What's New in VSP5.0?

VSP 5.0 is a major new release of the software. Features new since version 4.0 include:

Sampling Designs

- New design methods for: Combined Judgment / Probability Sampling, Eliminating redundancy in well networks, eliminating redundancy of analytes, trend analysis, and Compliance sampling of Unexploded Ordnance (UXO) Anomalies, Seasonal Kendall test for monotonic trend.

- New Data Analysis Features: Outlier Tests, Handling of Non-Detects, Geostatistical Analysis, and Correlation Analysis of Analytes.

- For UXO designs, the user may save power curves and choose which saved curve to display in the report view.

- Updated Transect Sampling for UXO Target Detection

- Simplified UXO transect design user-interface

- Simplified / Streamlined data handling for UXO target analysis

- Power curve generation for UXO transect designs

- Grid cell sampling added for UTL Designs

- One sample t-test tabs and report views where data fails normality test now shows MARSSIM sign test results.

- Mann-Kendall trend test added for time-series data

- Added DQA support for more sampling designs

Building Features:

- **Surface Type** Definitions

- **Surface Overlays** for embedding a different surface type in a sampling surface or for creating elevated horizontal surfaces such as the top of furniture.

Maps:

- Support for Latitude / Longitude maps

- New **Map Layers** command for exporting estimates and variances of kriged data.

- New **Create Lines for Areas** command for creating outlines around sample areas that don't currently have them.

- New **Color by Value** command to automatically color samples as well as sample areas based on the value of a built-in or user-defined parameter.

- New **Snap Edges** command to perfectly align edges and corners of adjacent sample areas when they do not exactly match up.

- New **Bisect** command to split a sample area into one or more parts.

- The **Sample Information** dialog now shows the type of **Surface** on which the sample is located.

- **3D** view of maps including 3D navigation tools, 3D sample areas, and 3D sample placement.

- User-defined properties capability added for Samples

- Improved map export / import.

- Ability to toggle target markers, swaths, and anomalies for UXO Designs

Miscellaneous

- The **Expert Mentor** is now available from the **Help** menu. This a menu of tutorials giving guidance and suggestions on **Systematic Planning** and **Setting Up VSP Sites and Maps**.

- Multiple Analyte support for most sampling designs including analyte input page, calculation of number of samples for each analyte, data analysis for each analyte, and updated reports showing each analyte.

- A **RCRA Version** is now available from the **Select VSP Version** dialog

- Data import directly from file

- Improved copy/paste support for data input page

- Support connection for COMPASS software

- Updated on-line Help and tutorials
- New/Updated reports

1.3 Installation and System Requirements

VSP 5.0 runs on Microsoft Windows operating systems (98, NT, 2000, Millennium Edition, CE, and XP). *Visual Sample Plan (VSP) Models and Code Verification* (Gilbert et al. 2001) documents the successful installation of VSP on personal computers operating with Windows® 95, 98, Millennium Edition, and Windows 2000. VSP is developed and successfully runs under Windows XP.

VSP will not run on Windows 95 or earlier Windows operating systems. VSP currently does not run on Macintosh® or UNIX®/Linux systems. Any personal computer with sufficient hardware to run one of the supported operating systems should run VSP. The *minimum* hardware recommended is

- 1 GHz processor
- 64 MB RAM
- 30 MB of free space on the hard drive.

The current version of the VSP setup file is available from **http://dqo.pnl.gov/VSP**. After the setup file is downloaded, installation of VSP is almost automatic. Simply run the VSP setup file, VSP50.exe (or later version), and follow the on-screen instructions. The VSP program and auxiliary files will be copied by default to the C:\Program Files\Visual Sample Plan folder (subdirectory). However, you may specify a different location for the files.

Once installation is complete, you will start VSP using option **Start** > **Program Files** > **Visual Sample Plan** > **Visual Sample Plan.** Alternatively, you may place a VSP shortcut on the desktop by selecting **New** > **Shortcut** from the menu obtained by right-clicking the mouse on the desktop. The appropriate command line for the default folder is

"C:\Program Files\Visual Sample Plan\VSample.exe".

VSP may be uninstalled using the Control Panel icon labeled Add/Remove Programs. You may access this option using the **Start** button and **Settings** > **Control Panel.**

New versions of VSP are often released as prototypes for testing. These demonstration versions have expiration dates. After the expiration date has passed, you will be given the option of continuing with the current version or going to the VSP website to download the latest version. Version 5.0 is not a demonstration version and does not have an expiration date.

1.4 Overview of VSP

Sampling is the process of gaining information about a *population* from a portion of that population called a *sample*. A key goal of *sampling design* is to specify the sample size (number of samples) and sampling locations that will provide reliable information for a specific objective (called the **Sampling Goal)** at the least cost. VSP does the required calculations for sample size and sample location and outputs a sampling design that can be displayed in multiple formats. VSP does not address sample collection methods. It assumes the sample support (amount of material in the sample) is sufficient and the sample is representative of the population. A few designs in VSP assume the sample is taken across an entire grid (say a 10 x 10 cm swipe), but most designs assume the sample is a point sample taken at an X,Y coordinate location, and has sufficient volume for measurement and testing. VSP addresses the trade-off between repeated analytical measurements on a single sample to reduce overall sample result variability (measurement quality objectives / MQOs) and provides a sensitivity table for comparing analytical methods of varying accuracy and cost.

VSP can be used to develop a new sampling design. It can also be used to compare alternative designs. VSP automates the mechanical details of calculating sample size, specifying random sampling locations, and comparing sample costs with decision error rates. These activities can be accomplished in the context of your own site map displayed onscreen with various sampling plans overlain on sample areas that you select.

The first thing you will do after opening the program is to import or construct a visual map of the study site. Next, you select the area or areas to be sampled. The **Sample Area** may be only a portion of the study site (see the circular sample area in Figure 1.1, upper left window).

Then, for the Sampling Goal that you select, VSP will lead you through the quantitative steps of the DQO process (Steps 6 and 7) so that the program has the information needed to compute the recommended minimum number of samples (sample size). You can enter sampling costs and test alternative designs against a fixed budget.

The locations of the samples over the Sample Area are determined by the specific sampling design (pattern) that you select. For some Sampling Goals, and for some assumptions about the population, only certain designs are allowed from a statistical theory perspective. For example, sequential sampling is appropriate only for the sampling goal of **Compare Average to a Fixed Threshold** when the population units can be assumed to be distributed normally. When there is a choice of designs, VSP displays a dropdown menu of the allowable designs.

VSP can be used for designing samples for environmental settings as well as building/room/surface settings. For environmental settings, site maps and aerial pictures can be loaded into VSP for sample placement. For buildings and rooms, a CAD drawing or floor plan are loaded. **Map View** displays samples placed on maps and room drawings. On a site map, VSP displays the sample locations for easy visualization (see Figure 1.1, upper left window). VSP also lists the geographical coordinates of the sample locations (see Figure 1.1, lower right corner), which can be saved and exported as a Drawing Exchange Format (DXF) or SHP file for use in a geographical information system (GIS) or saved as a text file for use in global positioning system (GPS) software.

Two additional output formats for the design created in VSP are available: a **Graph View** of the design (see Figure 1.1, upper right window), and a **Report View** (see Figure 1.1, lower left window). The Graph View displays either a Decision Performance Goal Diagram for Sampling Goals that involved selecting between alternative actions, or a performance graph comparing number of samples to a design parameter for the other classes of sampling goals. The Report View is a text report that describes the sampling design in detail. The report contains the input values, the assumptions, the cost of the design, VSP output, technical description of the sample size formula and algorithms used, and a sensitivity analysis table to assess what would happen if more or fewer samples are collected than the optimal number calculated by VSP.

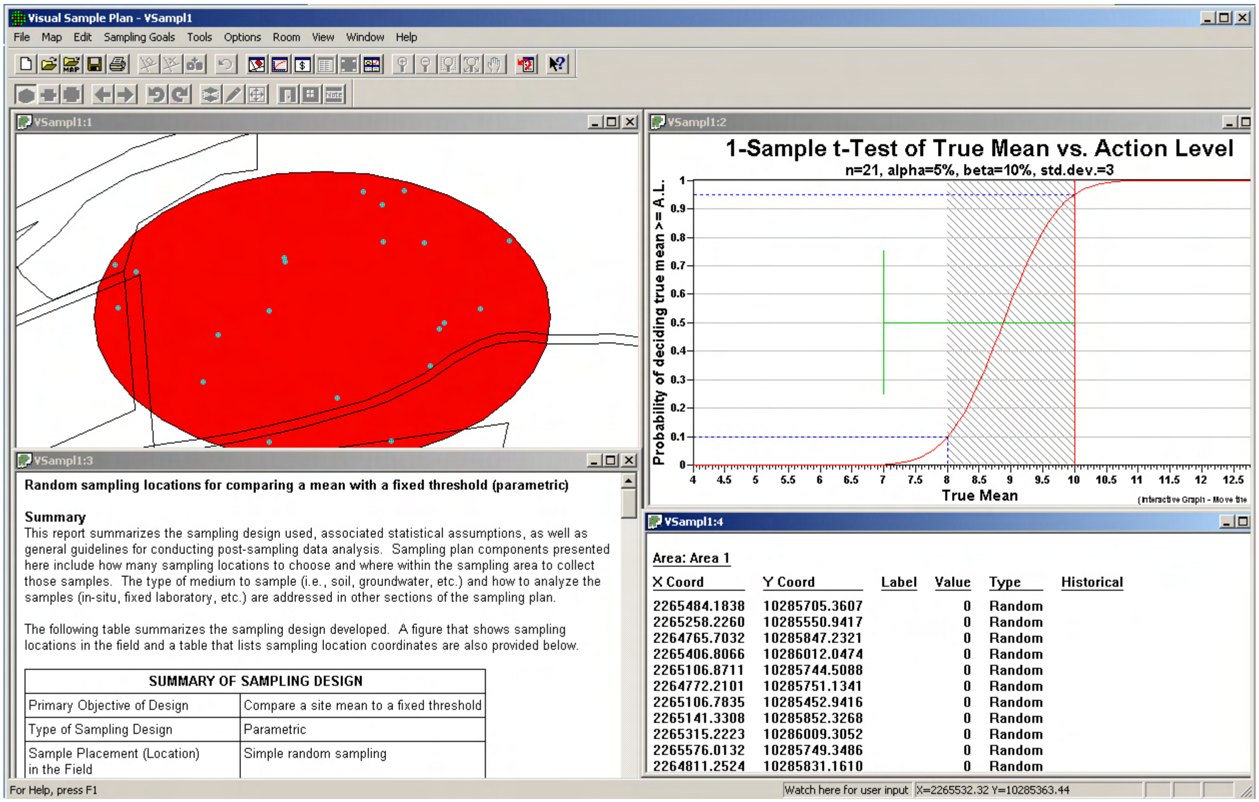


Figure 1.1. Screen Capture from VSP Using Quad Window Option (**Window** > **Quad Window**)

The analytical value of lab results for samples can be input into VSP for Data Analysis -- summary statistics of results, statistical tests applied to results for making decisions, and graphical displays of results. One of the designs, Sequential Sampling, requires intermediate results to be input to VSP so that VSP can determine whether further sample collection is required.

1.5 How Do I Use VSP to Provide a Defensible Sampling Plan?

To defend a sampling plan to a regulator concerned about safety ***and*** to a citizens' group concerned about saving taxpayer dollars requires balancing cost and risk. Defensible means that sufficient samples are taken, in a non-biased way, in order to make a decision, estimate a proportion, or declare an area free of UXO with a stated level of confidence. Additionally, once samples are taken and the results processed, someone needs to apply a statistical test to actually make a decision based on the data or calculate a confidence interval. VSP incorporates all this into the code it uses to calculate a sample size and sample locations. It asks the user to enter the assumptions, acceptable risk, and costs it needs for these calculations.

VSP follows the EPA-sanctioned planning approach for data collection and decision-making called the Data Quality Objectives (DQO) process. The DQO process achieves the user's limit on acceptable risk, at a minimum cost. See EPA (2000) for an extended discussion of the DQO process. There are 7 steps in the DQO process. Users must complete Steps 1 through 6 in order to have the inputs VSP needs. Then, using VSP, the user can complete Step 7, "Optimize the Design for Obtaining Data," because VSP can be used to try out different sampling designs and find the optimal design for the current problem.

Users familiar with the DQO process know that often a single site may have multiple sampling goals and multiple Sample Areas, each requiring its own set of DQO inputs and hence different sample requirements. VSP can help because it allows rapid prototyping and has many features that allow the overlay of designs and comparisons across designs.

2.0 Mechanics of Running VSP

2.1 Getting Started and Navigational Aids

Upon launching VSP, the first screen you will see is “Welcome to Visual Sample Plan” overlain with the initial navigational screen, **“Select VSP Version”** (Figure 2.1).

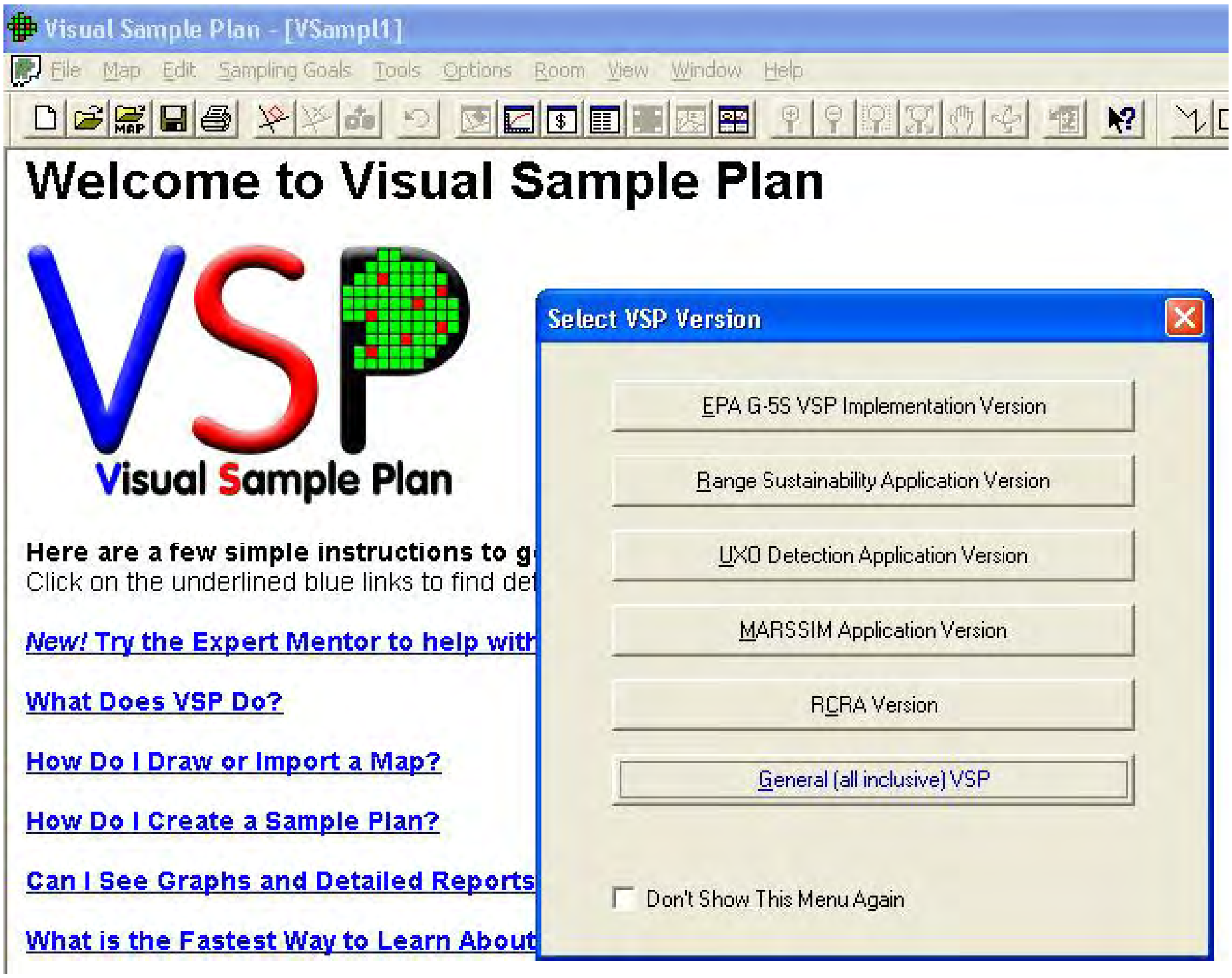


Figure 2.1. VSP Welcome Screen with Version Selection Menu

The choice of VSP versions is offered because different versions of VSP have been developed for different sponsors. Versions were designed to simplify the options presented to the single-purpose user as VSP became more complex. For example, users interested only in MARSSIM applications can select the MARSSIM version. That version contains menu items relating to only rooms and surfaces, and its statistical tests and sampling design options are limited to only those that are MARSSIM-approved. The **EPA G-5S VSP Implementation Version** implements only those sampling designs discussed in *Guidance for Choosing a Sampling Design for Environmental Data Collection* (EPA 2001). The **General (all inclusive) VSP** version provides access to all sampling designs and options.

Having selected a VSP version, you are now at the “Welcome to Visual Sample Plan” screen. The instructions on this page give answers to the most commonly asked questions from new VSP users. This screen will stay up until it is overlain with one of the View options, for example, when a map is loaded and you are in Map View.

You now are ready to begin using VSP after understanding one more piece of housekeeping. You have two ways to use VSP: pull-down menus from the top list of menu items, or the buttons on the main tool bar (select **View** > **Main Toolbar** to see the buttons). The pull-down menus offer a wider range of options. The buttons offer a quick one-click method for performing the primary VSP functions. Pull-down menus and buttons are shown in **Figure 2.2**. Holding the mouse over a button will reveal in text what that button does. For example, the Undo button is for undoing a key stroke during a map drawing session.

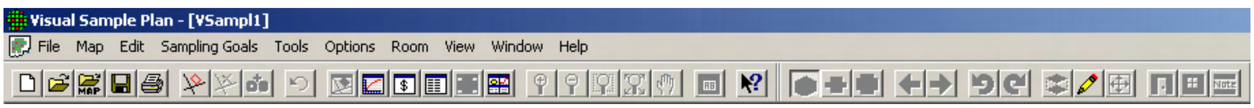


Figure 2.2. Main Menu Items (top row) and Buttons on the Toolbar (bottom row)

There are 4 separate toolbars: the main toolbar, map drawing toolbar, ranked set toolbar, and room toolbar. These toolbars can be moved around the screen by placing the mouse above the buttons on the toolbar and dragging to another place. Toolbars can be displayed or hidden depending on whether they are checked or not (see **View** pulldown list).

Starting with the **File** menu item on the top menu bar, the pull-down menu shows the various options for dealing with Projects.

VSP uses the term Project to refer to the map, report, sample information, and cost information associated with one sampling design. All this information is contained in the ‘filename.VSP’ created or selected by the user and is in a special VSP format file. Upon starting VSP, you either create a new project, **File** > **New Project**, or open an existing project, **File** > **Open Project** (Figure 2.3). If you are creating a new project, you will automatically be put into the “Welcome to Visual Sample Plan” screen after selecting **File** > **New Project**. If you are opening an existing project, you will be shown a list of existing VSP files and asked to select one. VSP doesn’t save information such as data loaded into Data Entry screens, or sample locations on a Map until **File** > **Save Project** is executed.

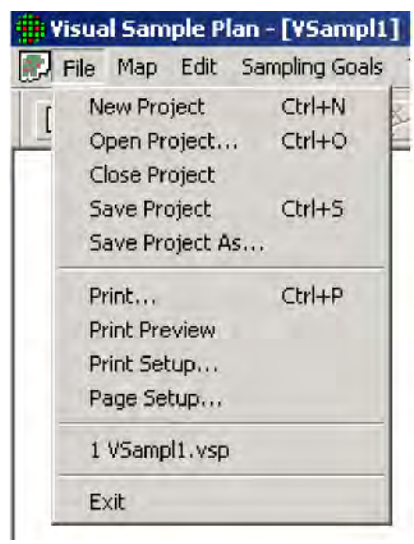


Figure 2.3. Pull-Down Menu Items Under File

2.2 Setting Up a Map

If you are starting a new project, you may obtain a map (drawing) of the site in any of three ways:

1. Import the site map from a drawing interchange format (DXF) file or ArcView SHP file. VSP supports the following DXF Objects: POLYLINE, LWPOLYLINE, LINE, ARC, CIRCLE, ELLIPSE, TEXT. If you are having problems loading a DXF file into VSP, try converting your file to these types of objects.

2. Import the site map from a previous VSP project that was saved in VSP format (i.e., a .VSP file).
3. Draw the map or Sample Area using VSP's drawing tools.

These three methods are illustrated below. VSP uses the coordinate system associated with the imported map. Because neither DXF nor SHP files contain the distance units, VSP will assume your map is in feet until you change it to some other unit. This is done by selecting **Map** > **Map Settings** from the Main Menu. If you want to use a local origin in your design, use **Map** > **Set Origin** to click on the map at the location you want to become the new origin (0,0 point). You can also input the current location via the keyboard to become the new origin. If the SHP map is in Latitude / Longitude, rather than a planar coordinate system, VSP will recognize it and offer to convert it to the Universal Transverse Mercator (UTM) system.

2.2.1 Importing a Site Map from a File

You can draw a complex site map in an architectural drawing program such as Autodesk Map© AutoCAD©, or ArcView© and save the drawing to a .DXF or SHP formatted file in that software package. The resulting file can be imported into VSP. The Millsite.dxf file is a sample DXF file provided with VSP. The following steps illustrate how to use this file in VSP:

1. From the main menu, select **Map** > **Load Map from File**. A quick alternative is to click on the **Load Map** button on the VSP toolbar.
2. A list of available files in the Visual Sample Plan folder is displayed. Select Millsite.dxf. You may change folder names to search for the desired file using standard Microsoft file-searching if the file is not in the Visual Sample Plan folder. Double-click on Millsite.dxf.
3. Choose whether or not you want to import the text embedded in the DXF file.

The site map should appear on your screen as illustrated in Figure 2.4.

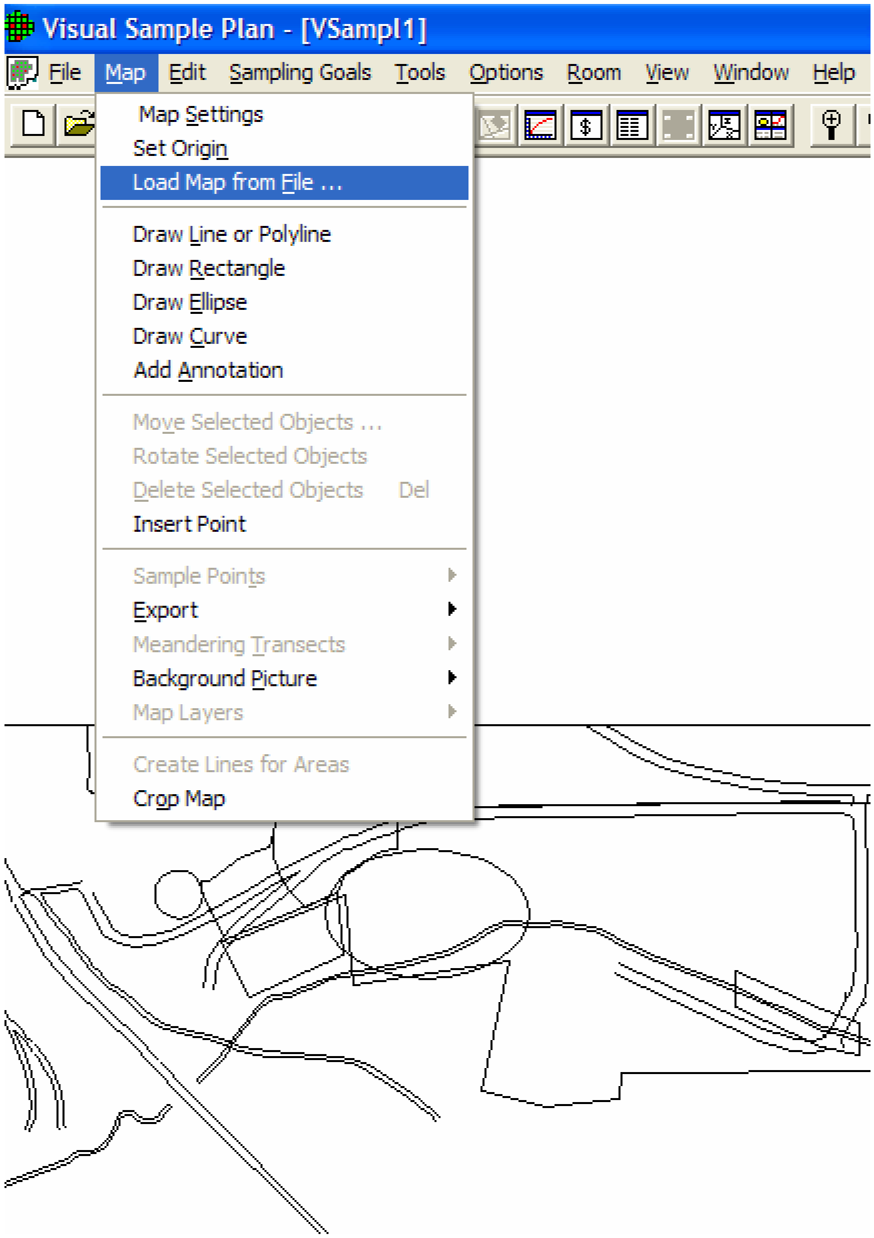


Figure 2.4. The Millsite.dxf File Opened in VSP, showing **MAP** Pull-down Menu

2.2.2 Importing a Site Map File in the VSP Format

To open a VSP-formatted file, from the main menu select **File** > **Open Project** or use the **Open** button on the VSP toolbar. A list of available .VSP files is displayed. Double click on the .VSP file to be opened. Switch folders and/or directories if the desired file is in another folder or directory.

2.2.3 Draw Map Using VSP Drawing Tools

VSP provides a basic set of drawing tools for users who do not have a drawing program to create a site map. You can experiment with the drawing tools as follows:

- Create a new project by choosing **File > New Project** on the Main Menu or by clicking the **New** button on the main toolbar. To dismiss the "Welcome to Visual Sample Plan" displayed upon opening a new project, simply commence one of the drawing operations outlined below or an operation in **Map > Map Settings**. If the project window is not full screen, expand the project window by pressing the **Maximize** button on the upper right corner of the project window.
- Choose **View > Map Drawing Toolbar** from the Main Menu. This displays a toolbar used specifically for drawing a map. This toolbar also may be docked if you prefer to remove it from the project window. To dock the drawing toolbar, place the mouse cursor on the blue title bar and drag the drawing toolbar onto the VSP toolbar.

All the drawing functions described below also are available from the Main Menu option **Map**.

Draw Line. Click the **Draw Line** button on the toolbar. The cursor will become a cross, indicating that you are in drawing mode. Click a point on the map. You will now see a line between the cursor and point you clicked. Continue clicking points to make a complex polygon. If you make a mistake, click the Undo button on the VSP toolbar (or select **Edit > Undo** from the Main Menu or press Ctrl-Z on the keyboard). This will remove the last point you entered.

Points can also be entered on the keyboard. Just enter the x, y coordinates for each point (for example: type **32,48** and press the Enter key). You can see the coordinates that you are entering on the status bar at the bottom of the window. To connect a line to a point already entered (for example, to connect the last line to the first point to create a closed polygon), hold the Shift key while clicking with the mouse. Holding the Shift key can be used in most drawing operations to select the nearest point on the map without having to carefully position the cursor. Holding the Ctrl key while moving the mouse allows you to draw a horizontal or vertical line without having to be careful. To finish the line, right-click the mouse or click the **Draw Line** button on the toolbar again.

Draw Rectangle. Click the **Draw Rectangle** button on the toolbar. Click on a point on the map that you want to be one corner of a rectangle. Holding the Shift key while clicking causes that point to be attached to an existing point on the map. Move the cursor to the opposite corner of the rectangle and click the mouse button. Holding the Ctrl key while moving and clicking forces the rectangle to be a square. The x, y coordinates of the corner points can be entered on the keyboard also.

Draw Ellipse. Click the **Draw Ellipse** button on the toolbar. Drawing an ellipse is basically the same as drawing a rectangle. Holding the Ctrl key forces the ellipse to be a circle.

Draw Curve. Click the **Draw Curve** button on the toolbar. Click a point on the map. Click a second point on the map. A line is drawn between these first two points. As you move the cursor around the map, this line is stretched to become a curve. When the curve has the shape you want, click the mouse (this is the control point). The x, y coordinates for the three points also can be entered on the keyboard.

Add Annotation. Notes (also called note objects) can be added to maps using the annotation tool. Select **Map > Add Annotation**, and the cursor becomes a crosshair. Click on the map at the location where you want to add the note object. The location may also be entered on the keyboard. A default object containing the text "Right-Click Here" is added to the map.

After the default object is added, use the mouse to right-click on the note object. A **Map Label Information** dialog box pops up, as shown in Figure 2.5. You will be able to change the following parameters:

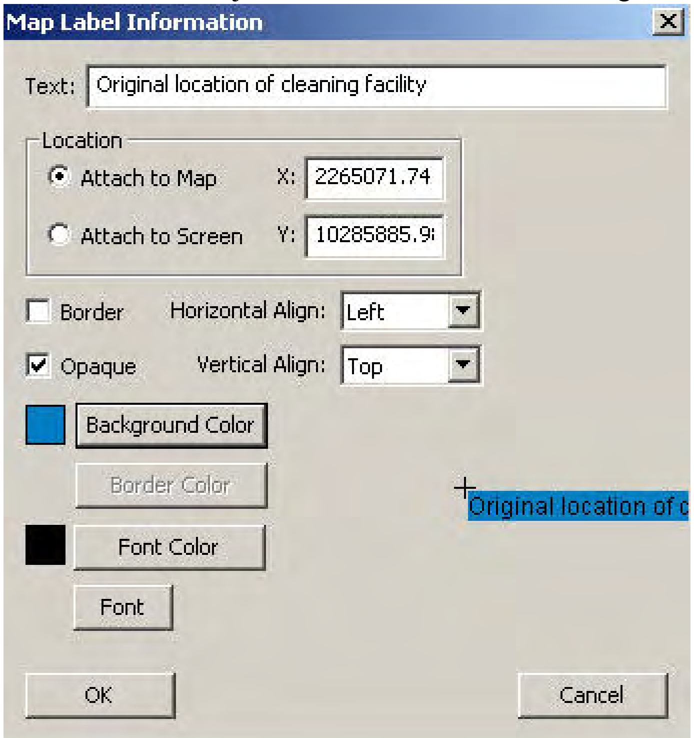


Figure 2.5. Map Label Information Dialog Box

- Note text
- Anchor point on map
- Anchor point to screen
- X and Y coordinates of anchor point (map or screen)
- Border, background color, and font
- Alignment (left/center/right, top/center/bottom)

2.2.4 Working with Maps

2.2.4.1 Selecting Lines and Notes on the Map

VSP imports DXF and SHP files and turns the objects into polylines or a series of connected points. Lines and note objects on the map can be selected by clicking on them with the mouse. When an object is selected, a small black box appears at each vertex, or point, on the object. Polylines appear as a series of vertices. Use the Ctrl key to toggle the selected status of a single line of note object.

Several lines may be selected by using a rectangular area. To do this, position the mouse at one corner of the rectangle then press and hold the left mouse button down while moving the mouse to the opposite corner of the rectangle. When the mouse button is released, all the lines and notes that pass through the rectangle will be selected. Use the Ctrl key to keep previously selected lines and note objects.

Move Selected Objects. Use this dialog to move the selected objects by the given offsets. Objects may also be moved by using the mouse. Position the mouse over a selected line or note object. Press and hold the left mouse button while moving the mouse to the new position. When the mouse button is released, the selected lines will be placed at the new position. This command applies to both map lines and annotation objects.

Rotate Selected Objects. After selecting this command from the menu, enter the pivot point by clicking with the mouse or entering the coordinates on the keyboard. Then enter the angle of rotation by moving the mouse and clicking or entering the degrees on the keyboard. This command affects all selected objects on the map.

Delete Selected Objects. This command deletes selected objects from the map. This action cannot be undone.

Insert Point. After selecting this command from the menu, click on the map with the mouse. A new vertex point is inserted in the nearest polyline on the map. If the polyline matches a sample area, then a matching vertex is also inserted into the sample area. After inserting a point into a polyline, it can be dragged with the mouse to a new location. See VSP's **Help > Help Topics > Menus > Map > Insert Point >** selecting and moving points and segments for more information.

Deleting Segments of a Map. If you want to remove a segment from either an imported map or a user-drawn map, you may click on a segment and hit the Delete key on your keyboard. Right-clicking on any segment in a map displays the vertices of the polyline in an outline of bold squares. With the outline in bold squares displayed, hit the Delete key on your keyboard and that segment is removed.

Map Buttons on the Toolbar. The **Zoom In**, **Zoom Out**, **Zoom Window**, **Zoom Max,** and **Pan** buttons in the middle of the VSP toolbar (and as pulldown items under Main Menu option **View**) provide methods to focus in on a Sample Area or other region of a site map. Press once on the **Zoom In** button and then click on the site map to make it grow larger. Turn off this mode by pressing the **Zoom In** button again. The **Zoom Out** button works the same way except that it makes the site map shrink. The location on the site map where you click determines the area of the new focus.

The **Zoom Window** button allows you to create an expanded rectangular window into the site map. For an example, press the **Zoom Window** button, drag the cursor across part of the screen, and release. The dashed lines illustrate the final window focus.

The **Zoom Max** button displays the map at the largest size that will fit the current view. VSP uses the current map extents to determine how the map will be positioned. Use **Map > Set Map Extents** to adjust the minimum / maximum x and y coordinates to use for this operation.

The **Pan** button repositions the map in the view window. Hold the left mouse button while dragging the map to a new location. When the left mouse button is released, the map will be redrawn at the new position.

2.2.5 Additional Map Features

The remaining pull-down menu items under **MAP** are specialty topics, some of which are discussed in other sections of this manual. They will be briefly defined here.

Sample Points imports and exports sample points to text files. It is discussed in Section 2.4.1. **Export** exports a map and/or samples to various file formats. **Meandering Transects** draws or imports meandering swaths from an ASCII text file to VSP. To draw meandering swaths on the map you must first enter the width of the swaths in the dialog that appears. Meandering swaths will only be added inside of existing sample areas. If you draw outside sample areas, the swaths will be clipped at the edge of the sample areas. This command works similar to the **Draw Line** command. Right-click with the mouse or re-select this command to stop drawing. This command is useful for creating swaths to be analyzed with **Sampling Goals > Find UXO Target Areas > Assess probability of target area traversal based on actual transect pattern**.

Map> Background Picture > Load from file loads a background picture from a graphics file into VSP. VSP comes with two sample pictures: VSPEx1 and VSPEx2. Once a picture file is loaded into VSP, sample areas can be located on the picture similar to how they are located on a map. **Map > Background Picture > Calibrate with Map** matches the background picture to the sampling map. **Map >Background Picture > Load World File** can be used if a Picture World File is available for the background picture. VSP's **Help > Help Topics > Menus > Map Menu > Background Picture > Calibrate with Map** describes this process in detail. Figure 2.6 shows the background picture VSPEx1 loaded into VSP with a yellow sample area labeled "Sample area 1" placed on the picture.

Figure 2.6. Background Picture (.jpeg image) Loaded into VSP as a Map, with Labels Added

Map > Map Layers > Kriged Data > Export Kriged Estimates and **Map > Map Layers > Kriged Data > Export Kriging Variances** can be used to export data once the "Geostatistical mapping of anomaly density" or "Geostatistical Analysis" dialogs have been used to calculate kriged data on a map. The file produced is a plain text file that can be opened in Notepad or other text editors, but uses the ESRI grid format to allow it to be read directly into ArcGIS or other programs that support the grid file format. The data will be exported as a rectangular grid composed of square grid cells. This means that if the kriged data present covers an irregularly shaped sample area, the kriged data will still be exported as a rectangular grid, with "no data" values present for those cells that fall outside the sample area, as shown in Figure 1. In addition, although VSP allows rectangular kriged data grid cells, the ESRI grid format supports only square grid cells. The smaller dimension of the kriged cells in VSP will be used as the ESRI grid cell size, so the results may appear distorted when imported into another program.

Create Lines for Areas creates outlines around sample areas that don't currently have them. These outlines are important, because they allow you to edit the size and shape of a sample area.

Crop Map removes portions of a map that are not currently visible on the view window. It is useful for removing large amounts of extraneous map lines that tend to slow down the display and other map functions.

Refer to Section 6.1.3 for a discussion of using CAD drawings of building floor plans to delineate rooms/sampling areas within the floor plan drawings.

2.3 Sample Areas in VSP

2.3.1 Creating a Sample Area

Once a map is created, a Sample Area must be created. A Sample Area is a region in which to locate samples. While most sample areas are enclosed, one of the Sampling Goals in VSP, Establish Boundary of Contamination, allows for an open type of sample area -- samples are located along a boundary. The user must identify the area to VSP in order to make sampling locations available. (Note: You can use any of the sampling designs except Judgment Sampling without a Sample Area defined, but they will not create sampling locations, only sample sizes.)

2.3.1.1 Define New (Closed) Sample Area

Press the **New Area** button on the VSP toolbar (or from the Main Menu select **Edit** > **Sample Areas** > **Define New Sample Area**). A **Color** dialog box appears (Figure 2.7b). Use this dialog to choose the color of the Sample Area. After the color is selected, a tooltip box appears on the map to provide information on the selection method. Figure 2.7c shows a red Sample Area along with the dialog boxes for creating it. Repeat the operation to create a second Sample Area.

There are two basic ways in which to create the Sample Area:

Figure 2.7a. Map with a Single Sample Area

1. **One-Step Method**. Position the cursor inside one of the enclosed areas on the map and right-click with the mouse. The Sample Area is created, and a dialog box appears. This dialog box shows the size of the Sample Area and allows you to change the units of the map. Click the **OK** button on the dialog when done.
2. **Corner-Selection Method**. Position the cursor on each corner of the Sample Area and left-click with the mouse. If you hold down the Shift key while clicking, the nearest point on the map will be selected. If you make a mistake in choosing a corner, use the **Undo** feature. When you have finished defining the Sample Area, either click the **Finish Area** button on the VSP toolbar, select Main Menu option **Edit** > **Sample Areas** > **Finish New Sample Area**, or right-click the last segment in the corner selection method. The area dialog box appears (Figure 2.7a), allowing you to change the map units. Note: A Sample Area cannot cross over itself. If this happens, an error message—"This area is invalid and will be removed"—appears.

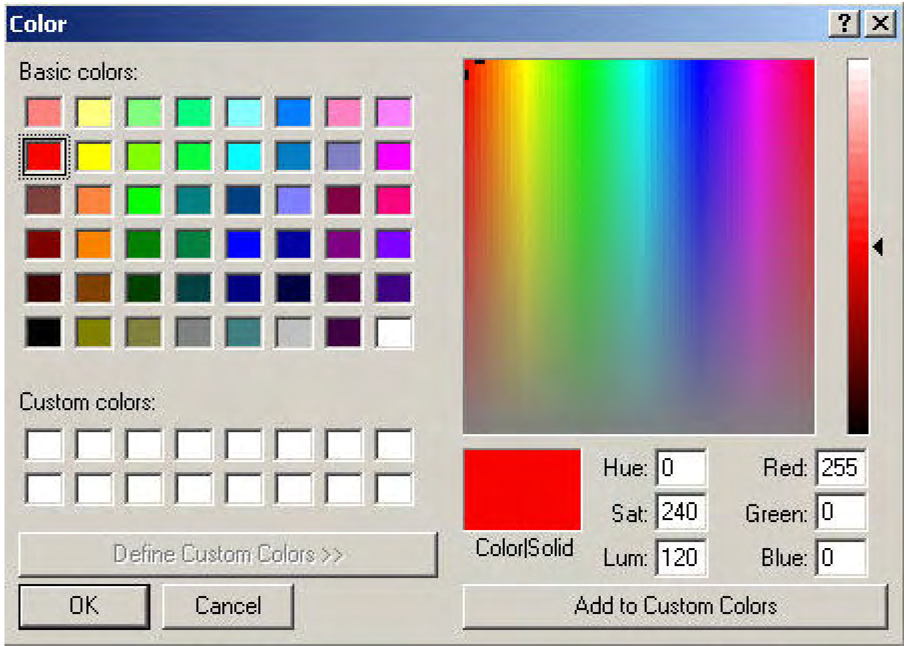


Figure 2.7b. (contd)

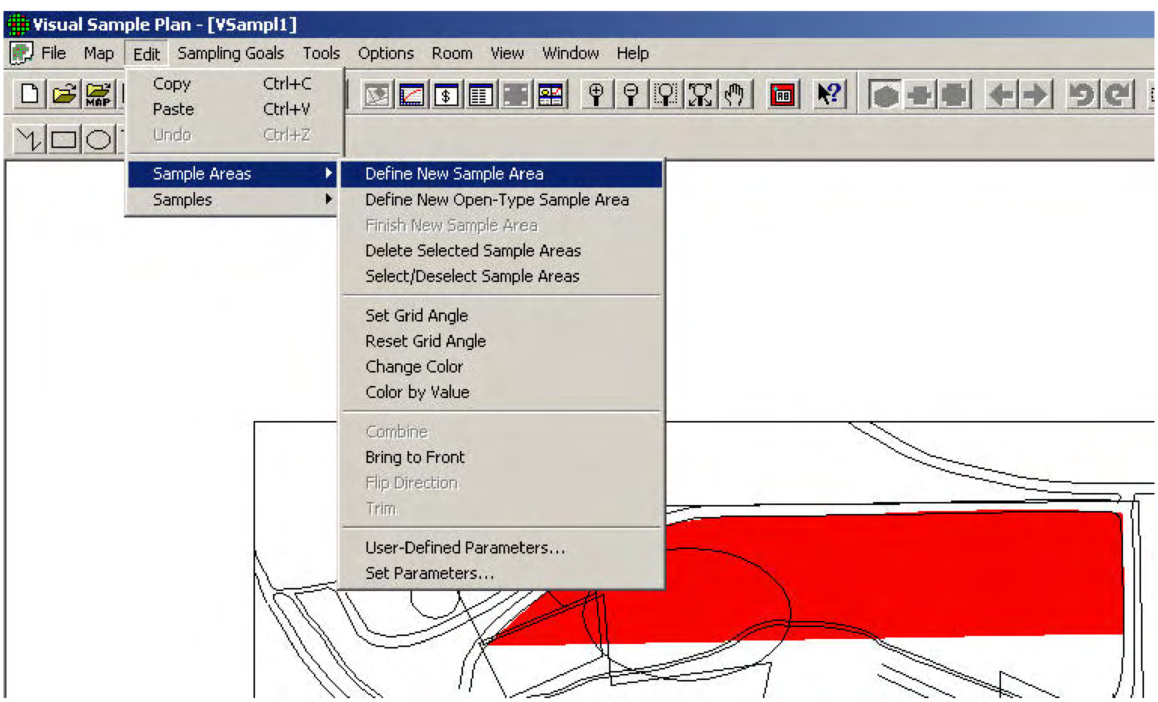


Figure 2.7c. (contd)

A map may contain a single Sample Area or multiple Sample Areas. For example, OneAcre.VSP (an example of a VSP file included with the program) is a single Sample Area, while Example1.VSP could have multiple Sample Areas because the map consists of several enclosed areas that could be selected as Sample Areas. When multiple Sample Areas are selected, samples located on the map by VSP are distributed across all the areas. When multiple samples area are combined using the VSP **Combine Areas** toolbar button or the **Edit > Sample Areas > Combine** menu selection, the combined area is treated as a single area (see Section 2.3.5 for a discussion of combining sample areas).

2.3.1.2 Define New Open-Type Sample Area

VSP provides sample design support for boundaries that do not completely surround a sample area. For instance, suppose it is reasonable to assume that the only portion of the boundary that could be breached by soil contamination is along the downhill side of the Sample Area. In that situation, the VSP user first clicks **Edit > Sample Areas > Define New Open-Type Sample Area**. Then the user places the cursor at the starting location of the desired partial boundary and clicks on each vertex along the boundary line until the end of the boundary of interest is reached. Then a click of the right mouse button finishes the creation of this partial boundary. An example of a partial boundary is shown as a red line in Figure 2.8.

Alternatively, the user may create an open-type sample area (partial boundary) using the single-click method. This is accomplished by selecting **Edit > Sample Areas > Define New Open-Type Sample Area** from the menu and then right clicking on an existing line on the map. The boundary may be shortened by selecting the **Edit > Sample Areas > Trim** from the menu and then clicking on two points on the boundary.

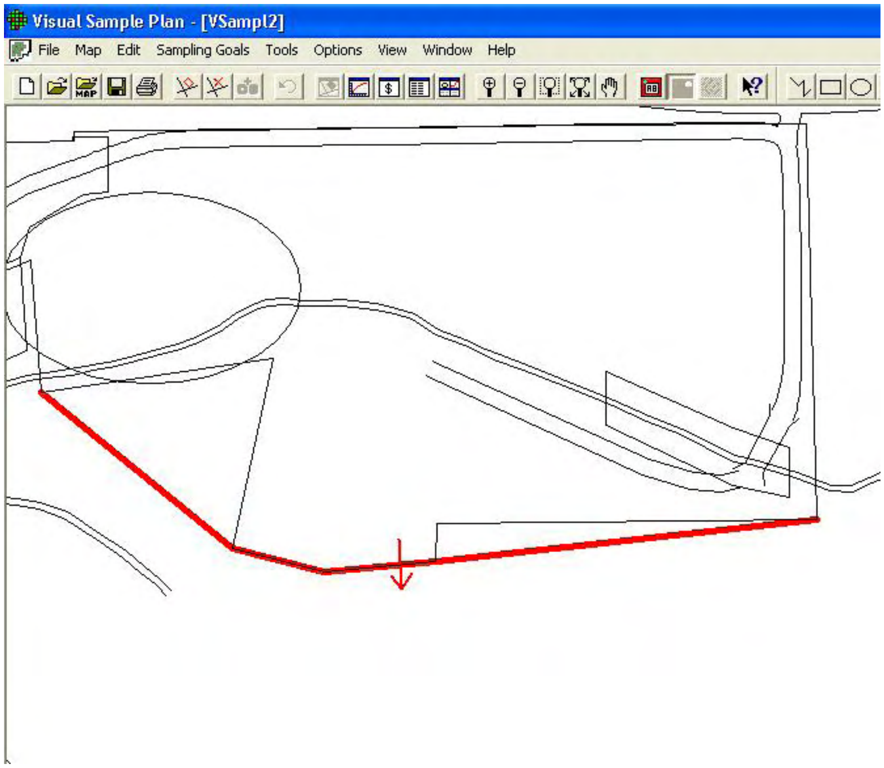


Figure 2.8. Example of an Open Boundary with an Arrow to Show the Direction the Soil Contamination would be Expected to Move (note that the arrow points toward the "clean" side)

During the boundary selection process, VSP places an arrow on the boundary. This arrow points in the direction that contamination in soil may be expected to move, if such movement has or were to take place. If VSP points the arrow in the wrong direction, the direction of the arrow can be reversed by clicking **Edit > Sample Areas > Flip Direction**.

2.3.2 Selecting or Deselecting Sample Areas

VSP allows the user to control which Sample Areas are available for locating samples. Creating a Sample Area automatically "selects it" for locating samples. You know it is "selected" because it appears in a solid color on the map. "Deselected" Sample Areas appear with only the outline of the Sample Area in color and the interior blanked out. You may Select or Deselect a Sample Area in three ways: 1) left click within the Sample Area, 2) right-click on a sample area and change the **Selected** checkbox on the **Sample Area Information** dialog box, or 3) from the Main Menu select **Edit> Sample Areas > Select/Deselect Sample Areas** (see Figure 2.9a). The latter method brings up a dialog box that allows you to choose which areas to select or deselect. Figure 2.9b shows a VSP map with three areas selected and one area deselected, and the dialog box where the selections are made. Note that VSP automatically names the Sample Areas: Area 1, Area 2, Area 3, and Area 4 according to the sequence in which the areas were created. The names can be changed in the **Sample Area Information** dialog box discussed in Section 2.3.4.

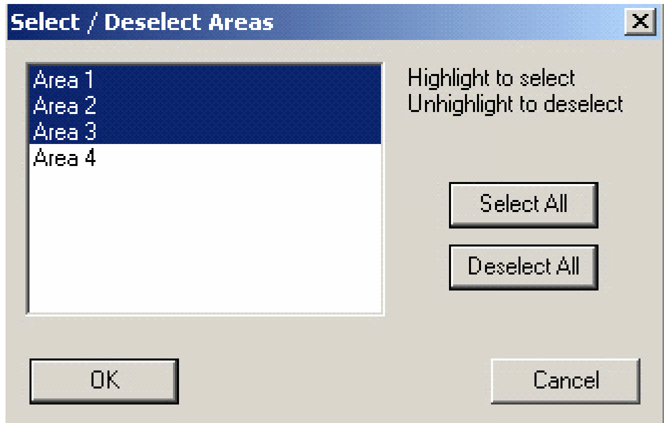


Figure 2.9a. Map with Multiple Sample Areas Selected

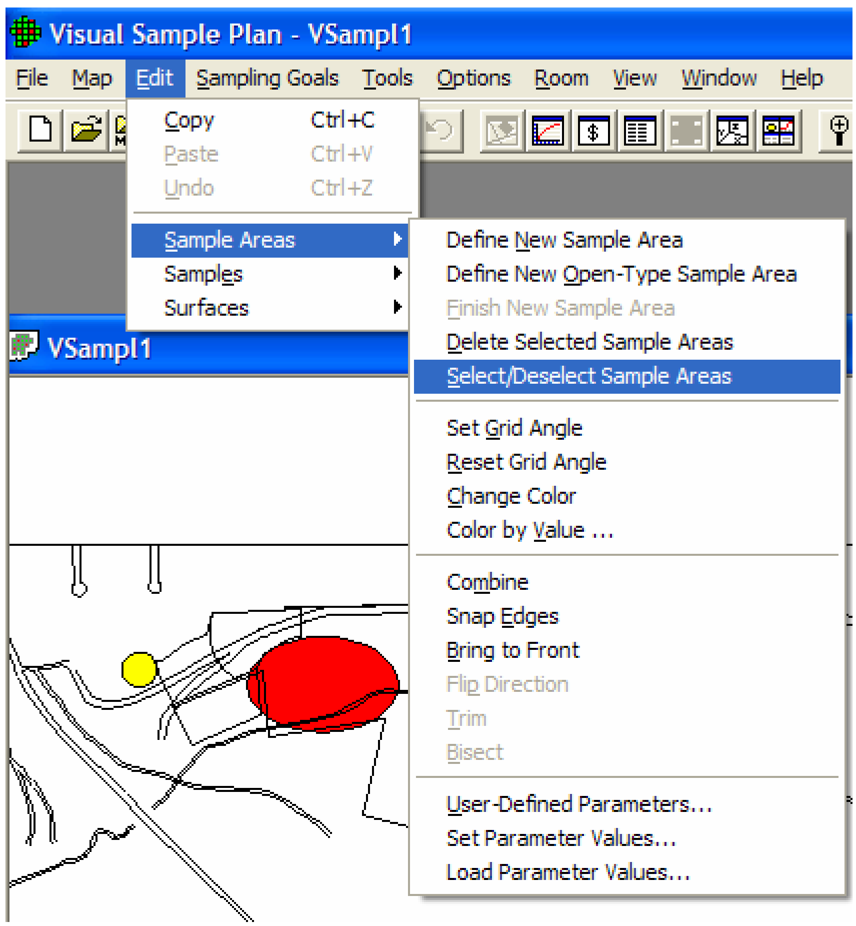


Figure 2.9b. (contd)

2.3.3 Deleting Selected Sample Areas

If you make a mistake, or just want to delete one or more of the Sample Areas you created, you must first make sure the Sample Area(s) is Selected (see above). Then, from the Main Menu, choose **Edit >**

Sample Areas > **Delete Selected Sample Areas**. Be sure to deselect any sample areas that you want to save.

2.3.4 Sample Area Parameters

VSP automatically generates certain parameters for Sample Areas, such as the name, area and perimeter. This information can be accessed by right-clicking on the sample area on the map. The **Sample Area Information** dialog box for Area 3, the big red ellipse, is shown in Figure 2.10.

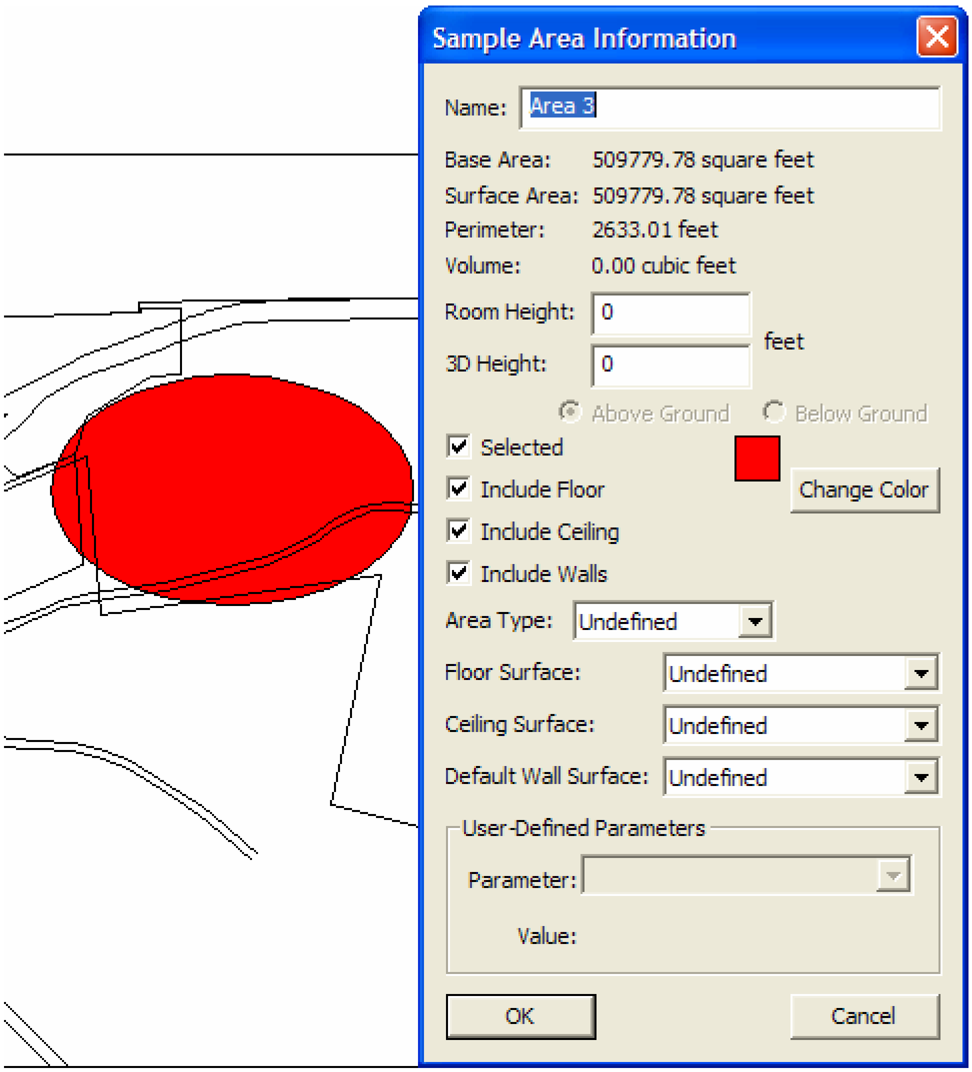


Figure 2.10. Sample Information Dialog Box for a Sample Area

Some parameters such as Name and Selected status can be changed in this dialog box. You will note parameters that refer to rooms in this dialog box. These will be discussed in Section 2.5. Briefly, Rooms are just Sample Areas with height greater than 0, so the same dialog box is used for both Sample Areas and Rooms.

VSP allows the user to define parameters for Sample Areas. These are called User-Defined Parameters. To create User-Defined Parameters, from the Main Menu select **Edit > Sample Areas > User-Defined Parameters**. A dialog box as shown in Figure 2.11 is displayed.

Press the **Insert New** button, and default values appear in the windows. Say you want to define a new parameter for Sample Areas and name it "Regulatory Status". Type "Regulatory Status" in the **Name** box. Say you select "Integer" for **Type**, and check the **List** option. **List** lets you limit the values assigned to Regulatory Status to those you supply. Figure 2.12 displays the dialog box for User Defined Area Parameters.

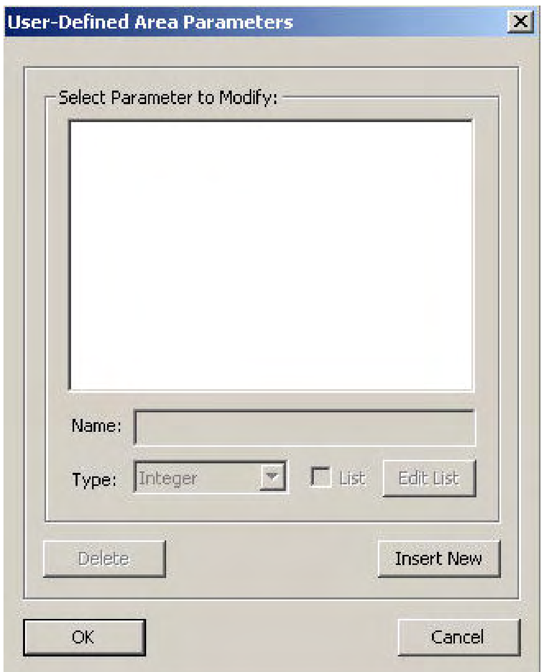


Figure 2.11. User Defined Area Parameters Dialog Box

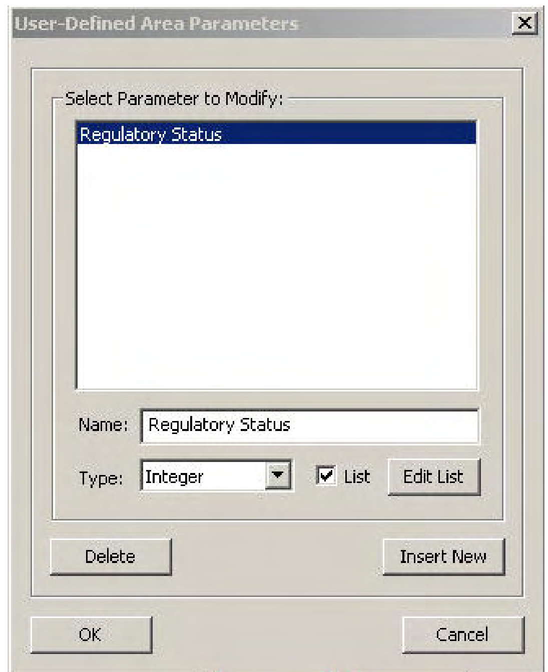


Figure 2.12. User Defined Area Parameters Dialog Box

With a parameter highlighted in the Select Parameter to Modify window, hit the **Edit List** button. A new dialog box titled **Parameter List Values** comes up (see Figure 2.13). The user inputs values to this list by putting the mouse on a current value, hitting return, and typing the next value into the list. The list contains the valid arguments for that parameter.

Once a new parameter is defined, that parameter is attached to (or defined for) all Sample Areas. You may want some Sample Areas to have one value for the parameter, and other Sample Areas have another value. Parameter values may be set in the **Sample Area Information** dialog or by the **Edit > Sample Areas > Set Parameter Values** menu command.

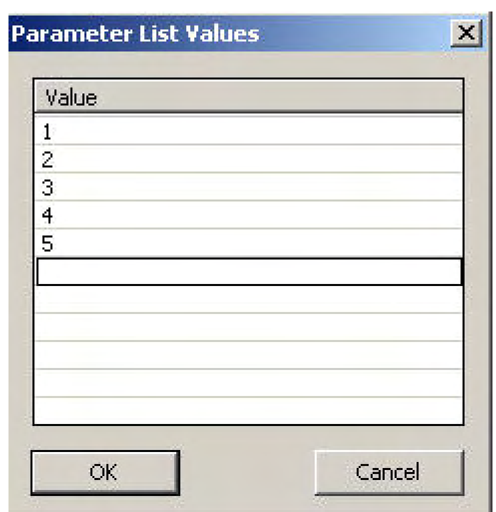


Figure 2.13. Parameter List Values Dialog Box

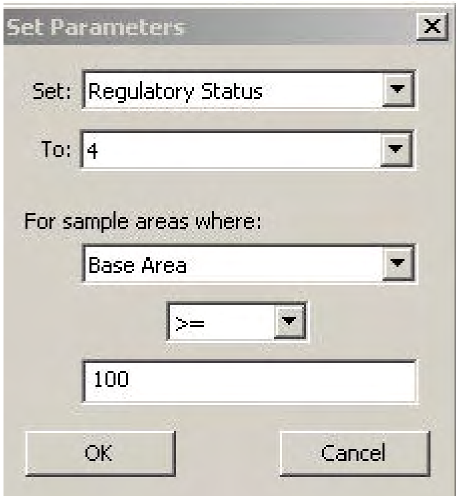


Figure 2.14a. User-Defined Area Parameters Dialog Box with Edit List

Shown in Figure 2.14a, the **Set Parameters** dialog box allows the user to assign parameter values to Sample Areas based on a condition. The example shown in Figure 2.15a says to set the parameter Regulatory Status to the value 4 for Sample Areas that have a Base Area (one of the VSP-defined Sample Area parameters) greater than or equal to 100 square feet. The Set Parameters dialog box has many pull-down lists, making it easy for the user to quickly set parameter values for Sample Areas.

If the user wants to set the value of built-in and user-defined parameters for sample areas or rooms from previously defined sources, use the **Edit > Sample Areas > Load Parameter Values.** Figure 2.14b is an example of loading parameter values into VSP from an external table. Currently, VSP only supports Tab delimited text for the input file or from the clipboard. The source would be a row/column table where parameter values are defined. The user uses the Column to Parameter Mapping to specify whether a column in the table is to be compared to a parameter or whether the column should be loaded into a parameter. For a complete discussion of this tool and an example, use the **Help** tool – select the "**?**" button on the toolbar, and move the cursor to **Edit > Sample Areas >Load Parameter Values**.

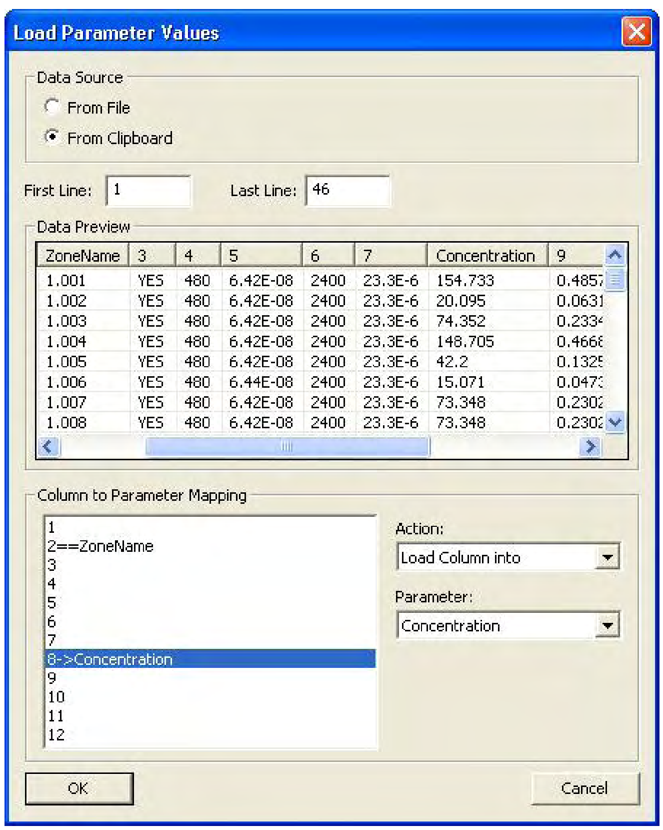


Figure 2.14b. Dialog Box for Loading Parameter Values in VSP From an External Table

2.3.5 Extended Sample Area Topics

There are several other features that deal with Sample Areas:

Set/Reset Grid Angles. Use this command to align gridded samples for selected sample areas. Left-Click with the mouse on one vertex of a sample area, then Left-Click on an adjacent vertex of a sample area. (Hold the shift key while clicking to select the exact point on the map.) Use the **Reset Grid Angle** command to change the grid angle back to its default setting.

Change Color. Use this command to change the color of all selected sample areas. The chosen color will also be the default color for subsequent new sample areas.

Color by Value. Use this command to automatically color all sample areas (or rooms) based on the value of a built-in or user-defined parameter. Select one of the defined color sets to use for coloring the sample areas. Some color sets are gradient and some are discrete. Select one of the built-in or user-defined parameters to use for coloring the sample areas. Use the **log scale** box to color scale the parameter according to the logarithm of its value. Only certain parameters can be log-scaled. Check the **Color by Value** box to color the sample areas by the value of the given parameter. Uncheck this box to turn off this automatic coloring feature.

Combine. This command combines sample areas or creates interior holes in sample areas. To combine sample areas, select 2 or more non-overlapping sample areas on the map and use this command. The sample areas are combined so that they are treated as a single sample area. Clicking on one part of the sample area will select or deselect all the attached parts of the sample area. All the attached parts are treated as a single sample area for the purpose of sample placement. See **Help > Help Topics > Menus > Edit menu > Sample Areas > Combine** for an example.

Snap Edges. When edges and corners of adjacent sample areas to not exactly match up, use this command to perfectly align them. The edges must be fairly close to each other, they may even overlap slightly. After using this command, the edges will not overlap nor have any space between them.

Bring to Front. Use this command to bring the selected sample areas to the end of the draw list causing them to be drawn last. This will, in effect, cause them to appear in front of other sample areas. Use this command for sample areas that exist inside the hole of another sample area and cannot be seen. Note that this command changes the sample area numbers.

Flip Direction. This command switches the contaminated / uncontaminated side of the open-type sample area. The arrow points toward the uncontaminated side.

Trim. This command allows you to shorten the open-type sample area. After selecting this command, the cursor becomes a cross-hair. Use the mouse to click on two points on the open-type area. After the second point is selected, the area will be truncated at the two points.

Bisect. Use this command to split a sample area into one or more parts. To bisect: (1) Draw a line on the map that crosses the sample area one or more times, (2) Select the line, (3) Choose this command from the menu.

2.4 Individual Samples (Importing, Exporting, Removing, and Labeling Them as Historical)

Individual samples have several attributes within VSP:

- location (x, y, z coordinates) and local coordinates (lx, ly)
- type (sampling design used to collect them)
- Surface (on which surface it is located)
- label (descriptive text)
- value (numerical value)
- Shape (marker symbol)
- historical sample indicator (true/false indicator).

Some of these attributes are relevant for only certain functions within VSP and are explained in future sections.

The primary way you will locate samples within a Sample Area is by pressing the **Apply** button from one of the dialogs once a **Sampling Goal** is selected from the Main Menu. This process is described in Section 3. Samples located in this way are automatically assigned Location, Type, Surface, and Shape. Samples that are imported and samples that are located manually do not have the same status as those located by VSP using a statistical approach. Imported samples and manually located samples must be assigned attributes by the user.

Sample attributes can be displayed using the **Sample Information** dialog box. With the map displayed, right-click on an individual sample. A Sample Information dialog box appears that displays current sample information. Information such as Label and Value can be assigned using this dialog box. In Figure 2.15, we see the VSP file Example 2, after right-clicking the right-most sample in the third row up from the bottom. We assigned that sample a Label of “A-24”, and a value of “6.1”. The fact that the **Historical** box is not checked means this sample originated from VSP by Applying one of the VSP Sampling Goals (rather than being imported into VSP as part of an earlier sampling effort).

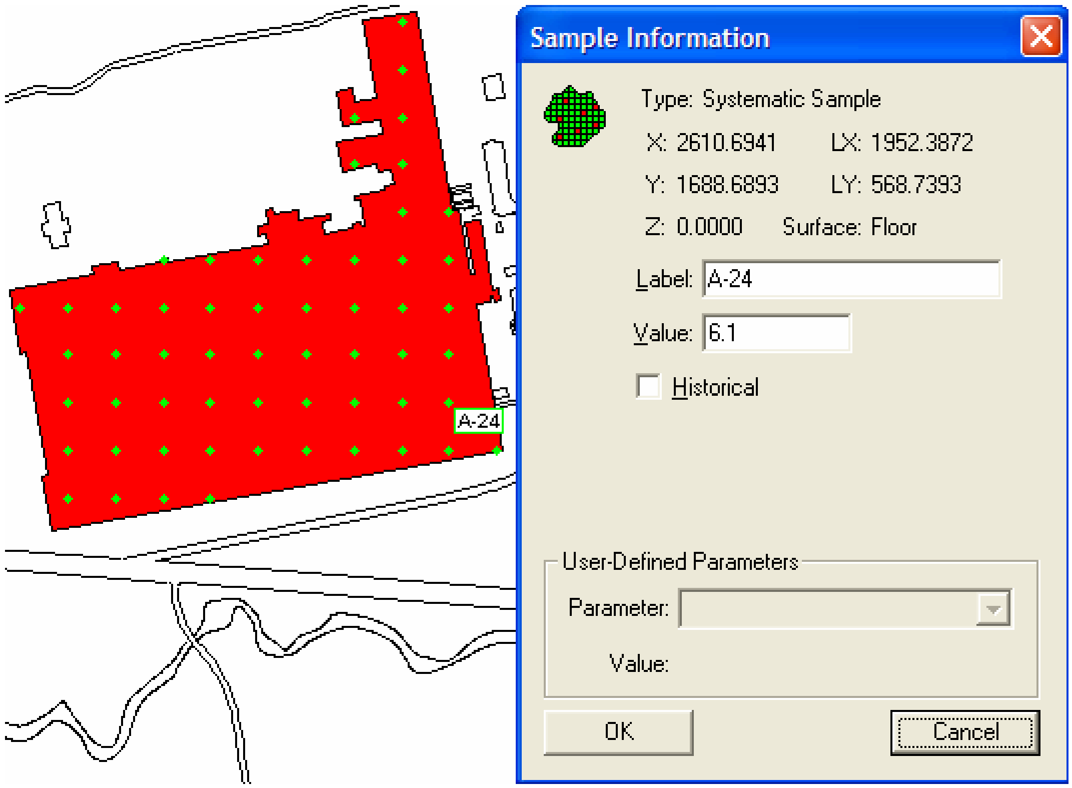


Figure 2.15. Sample Information Dialog Box for a Sample in Example2.VSP

2.4.1 Importing Samples

There are two ways to import sampling locations:
Copy them from the Windows Clipboard. Edit the coordinates in a text editor, a word processor, or a spreadsheet. Each line (or row) represents a different sampling location. The first column is the x coordinate; the second column is the y coordinate. The third column is the sample Type and is optional. Valid sample Types are Random, Systematic, Hotspot, Manual, Adaptive-Fill, Unknown, Transect, Compliance Transect, Meandering Transect, Ranked Set, Cluster, Grid Cell, Perimeter, Collaborative, Hot Spot Cell, Increment).

1. . The fourth column is the sample label and is optional. Spaces or tabs should separate columns. (Tabs are preferable.) The coordinates must lie inside a selected Sample Area.

Example: Type the following coordinates into a text editor such as Notepad:

10	10	Random
50	10	Systematic
10	50	Hotspot
95	60	Manual
99	99	Adaptive-Fill
150	150	Unknown

Now press Ctrl-A to select all the text and Ctrl-C to copy the text to the Windows Clipboard. Run VSP and load OneAcre.Vsp. Select the Main Menu option **View** > **Coordinates**. Paste the coordinates into VSP using either **Ctrl-V** or Main Menu option **Edit** > **Paste**. View the new sampling locations using the Main Menu options **View** > **Map** or **Window** > **Quad Window**. Your map view should now look like Figure 2.16.

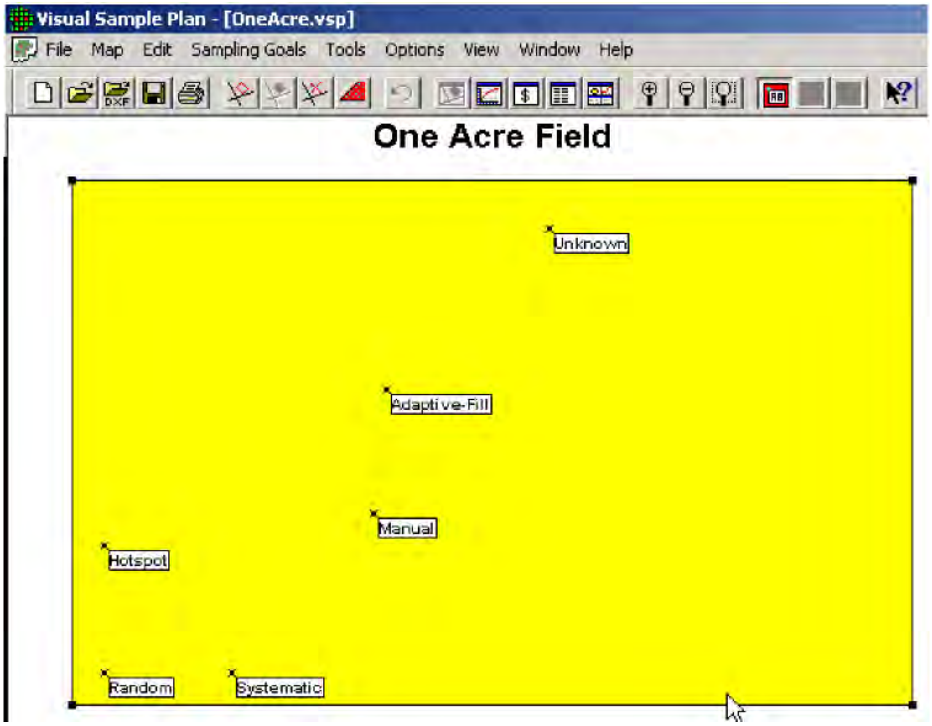


Figure 2.16. The OneAcre.VSP Project with Sampling Locations Added from Windows Clipboard

You can place the mouse on any sample point and right-click to see the attributes of the sample at that sample Location. Figure 2.17 shows the Sample Information VSP has for the sample near the arrow.

2. Import sampling locations from a text file. The text file must be formatted as described above. Choose Main Menu option **Map** > **Sample Points** > **Import** and enter the file name in the dialog box.

Samples that are imported are assigned Shapes depending on the Type attribute assigned. Sample Type can be edited by selecting **Edit** > **Samples** > **Shapes** from the Main Menu. The Dialog box that appears shows both the shapes assigned to valid Types (use the pull-down menu to select among valid Types), and gives a picture of the Shape. Figure 2.17 shows that when a sample was collected according to a **Manual** design, it will be displayed with a **Small Square** within a **Large X** Shape.

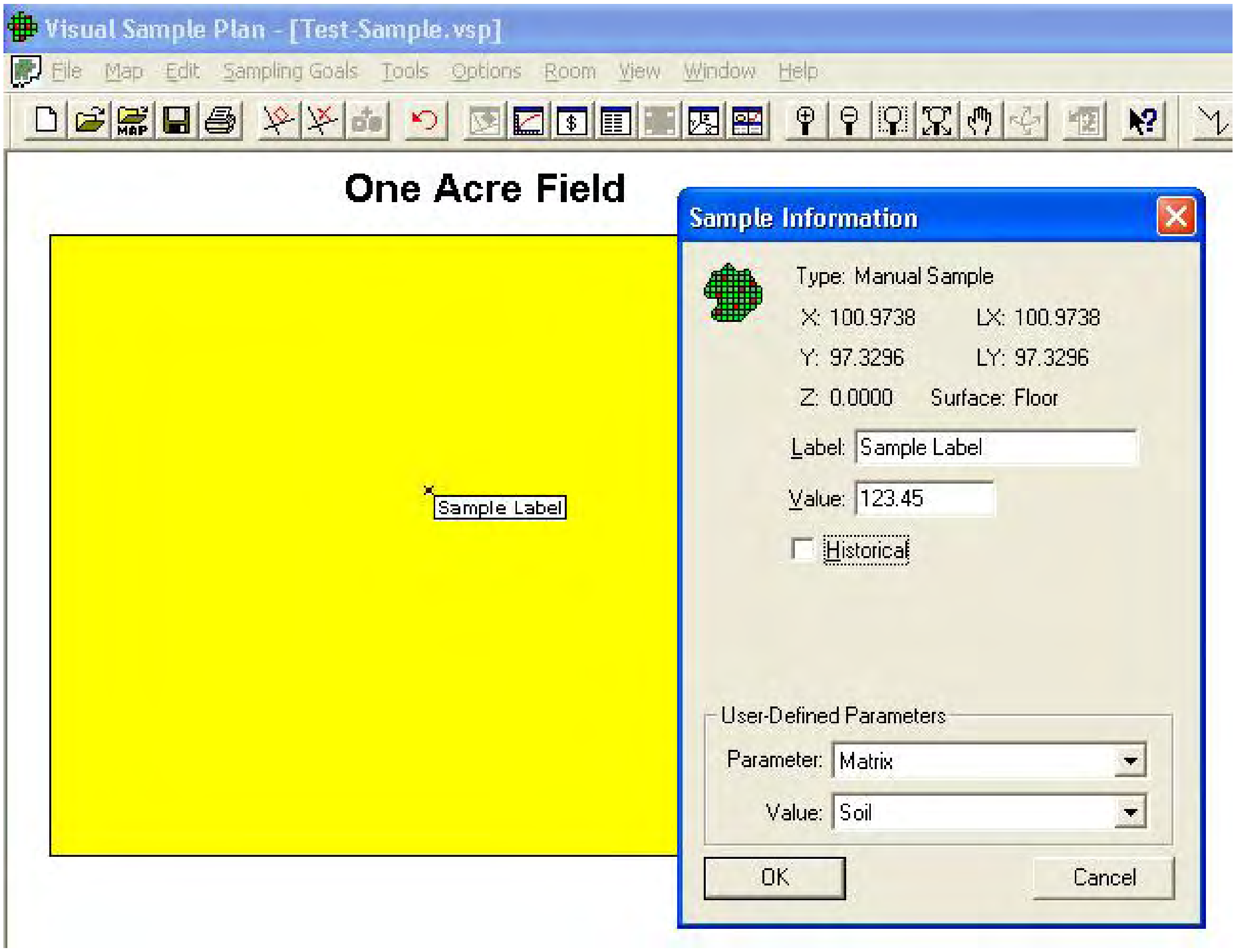


Figure 2.17. Example of Sample Information Box

2.4.2 Historical Samples

Sample locations with the Historical box checked have a unique role in VSP. VSP gives you "credit" for them in accounting for the total number of new samples needed. This is explained in Section 3.2. The important point to remember here is that if you import samples, manually add samples, or have a sampling design previously created within VSP, you can give specific samples a "Historical" status by placing your mouse over the sample location while in Map View and, in the dialog that comes up, checking the Historical box.

2.4.3 Exporting Sampling Locations

To export sampling locations to a text file (for example, to use the coordinates in a ground penetrating radar system),

1. Select the Sample Area as described above and develop the sampling design as described in Section 3.
2. Choose Main Menu option **Map** > **Sample Points** > **Export**. Provide a name for the text file and click Save.

2.4.4 Removing Sampling Locations

This option is best explained with an example:

1. Start VSP and open a new project using Main Menu option **File** > **New Project**
2. Open the Millsite.dxf file using Main Menu option **Map** > **Load Map from File.**
3. Click the **New Area** button on the toolbar and, after choosing a color, select the large ellipse by right-clicking inside the oval. If you accidentally get some other area, click the **Remove Areas** button and start over. Place the cursor as far from other objects as possible but still inside the ellipse.
4. Choose the Main Menu; select **Sampling Goals** > **Compare Average to Fixed Threshold** > **Data not required to be normally distributed** > **Ordinary sampling of symmetric distribution**. Click the Apply button to place samples in the Sample Area. You should now have a Sample Area with 24 sampling locations similar to that shown in Figure 2.18.

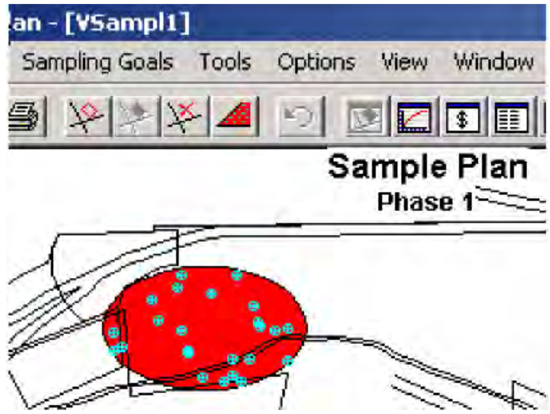


Figure 2.18. Example Sample Area with Sampling Locations

5. Using the Main Menu option **Map** > **Sample Points** > **Export**, save all the sampling locations to a text file named ***Points.txt***.
6. Now we are ready to remove some of the sampling locations. First, delete the first 16 rows (sampling locations) from file ***Points.txt*** using a text editor like Notepad. Save the remaining 5 rows to a new file named ***Remove.txt***. These are the locations that will be *removed* from the Sample Area.
7. Finally, to remove the sampling locations listed in Remove.txt from the Sample Area, choose Main Menu option **Map** > **Sample Points** > **Remove**. Select the file ***Remove.txt*** and click the **Open** button. You will see in Figure 2.19 there now are only 16 sample points instead of the original 24 shown in Figure 2.18.

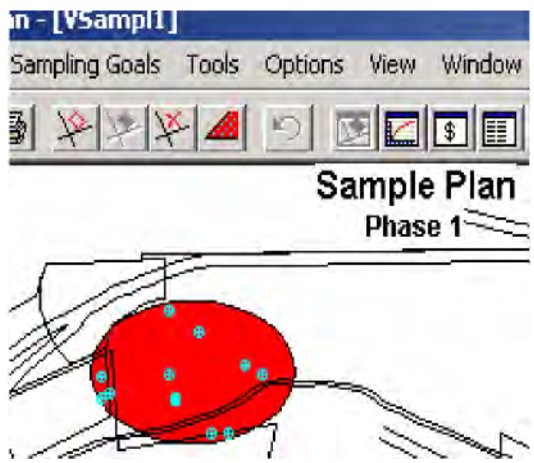


Figure 2.19. Example Study Area after Sampling

In other words, the coordinates in the ***Remove.txt*** file are the sampling locations that are deleted from the Sample Area. Just one location or all the locations can be removed.

2.5 Rooms and Buildings in VSP

The current version of VSP has the ability to draw and apply sampling designs to rooms and hence, buildings. Rooms have height, spatial relationships with other rooms (i.e., can be assigned to floors within buildings), and a unique set of objects associated with them (e.g., doors, windows, and surface overlays). They also have a unique set of parameters that are VSP-assigned (e.g., volume, floors, ceilings, walls) and user-assigned (e.g., zones, class, HVAC system, release point of threat agent, etc.).

At the most basic level, a Room is just an enclosed Sample Area with height greater than zero. As such, many of the VSP functions and screens associated with Sample Areas are the same for Rooms. However, there are also many VSP functions used exclusively for Rooms.

A Building is a collection of rooms. A Building is input into VSP by loading a .dxf map file. Rooms, stairways, and elevators within the building upon which you wish to place samples need to be defined to VSP by using the **Room > Delineate Rooms** function. Use the mouse to follow the outline of a room or a stairwell on the CAD drawing (i.e., a floor plan .dxf file) to define room shape and size. See Chapter 6 Room Features in VSP.

2.5.1 Drawing a Room

Start a new project using Main Menu option **File > New Project**. Click the **Draw Room** button on the Room Toolbar or select Main Menu option **Room > Draw**. (Use **View / Room Toolbar** to show the Room Toolbar.) A tooltip box displays the three ways to draw a room using this tool:

- Enter the room dimensions on the keyboard: LxWxH. (e.g., 12x10x8 <enter>)
- Enter the corners of the room on the keyboard: X, Y (e.g., 50, 50 <enter> 90,90 <enter>).
- Left-click the mouse at the upper-left hand corner of the room, and drag the mouse to the lower-right hand corner. Left-click the mouse to finish the room. This is similar to drawing a rectangle, except that VSP automatically sets a wall height of 8 ft. Room height can be changed using Main Menu item **Room > Set Room Height** or by clicking on the **Set Height** button on the drawing toolbar.

With the room displayed, right-click anywhere within the room. The **Sample Area Information** dialog box appears (Figure 2.20).

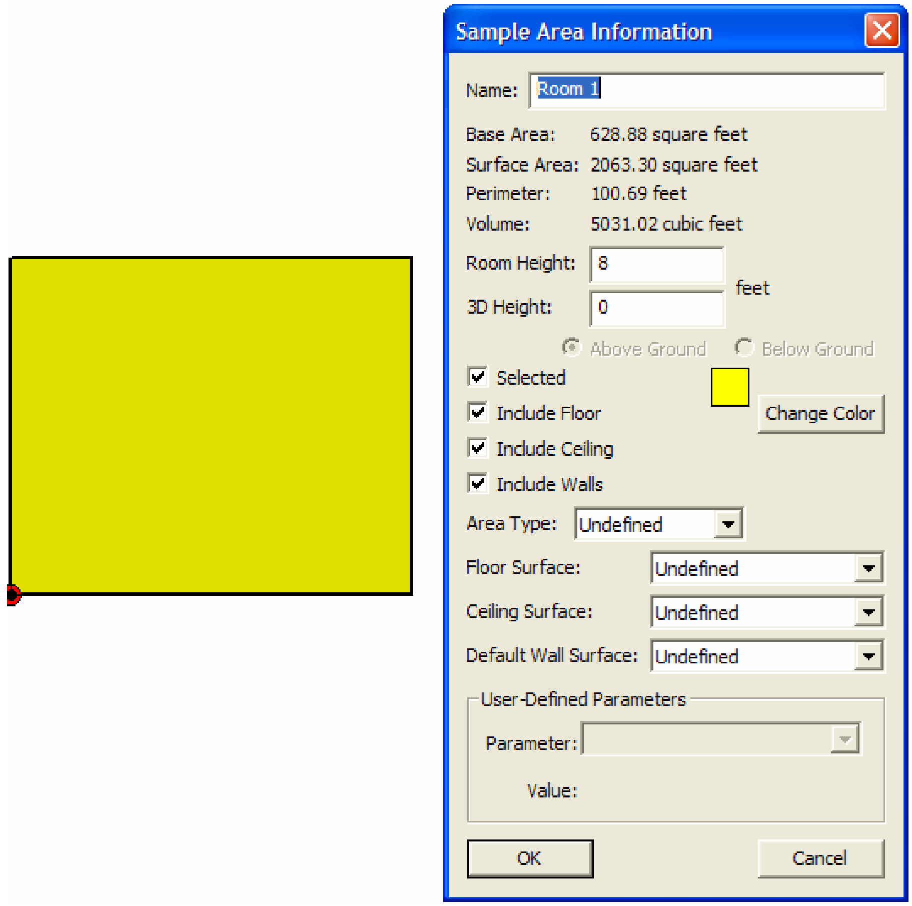


Figure 2.20. Sample Area Information Dialog Box for a Room

This dialog box can be used to view parameters of the room such as base and room area, perimeter, and volume. The name of the room is set to "Room n" until changed by the user. The user can set and change other parameters such as room height, color, whether the floor and ceiling are included as part of the room (and hence samples will be applied to the floor and ceiling as well as the room walls). Any User-Defined Parameters set will be displayed in the pull-down list. User-Defined Parameters for Rooms are set in the same way as User-Defined Parameters for Sample Areas (see Section 2.3.4). Note that you are in Map View when drawing the room.

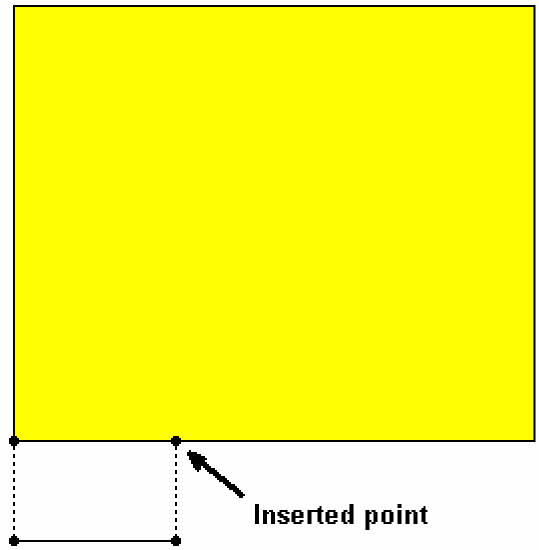


Figure 2.21. Room with Inserted Point

The room can be modified in the Map View by inserting a point(s) into a wall and then moving the wall section (see Figure 2.21). This is used to create L-shaped rooms, or irregular-shaped rooms.

Use Map > Insert Point and click on one edge of the room. Hold down the Shift key and left-click on the segment to select it. Now move the segment out from the room by dragging it with the mouse (move while holding down the left-mouse button).

You can set the exact length of a line segment by right-clicking on it. First select the segment (hold the Shift key while clicking between two points on the map), then right-click on the selected segment. A dialog will appear that allows you to enter the exact length of the line segment. If the segment is attached to other segments at right angles, those other segments are moved or adjusted as well.

After the room is drawn (defined), it becomes the current room and can be displayed with Room view (**View** > **Room**). The current room is indicated on the map by a thick black outline and a darker shade. A room can be displayed in one of three view formats:

- Perspective
- Wall Strip
- Splayed

The display view format can be selected using one of the three buttons on the drawing toolbar, or by selecting one of the formats under the Main Menu item **Room** while in Room view. Figure 2.22 shows the three views of a room.

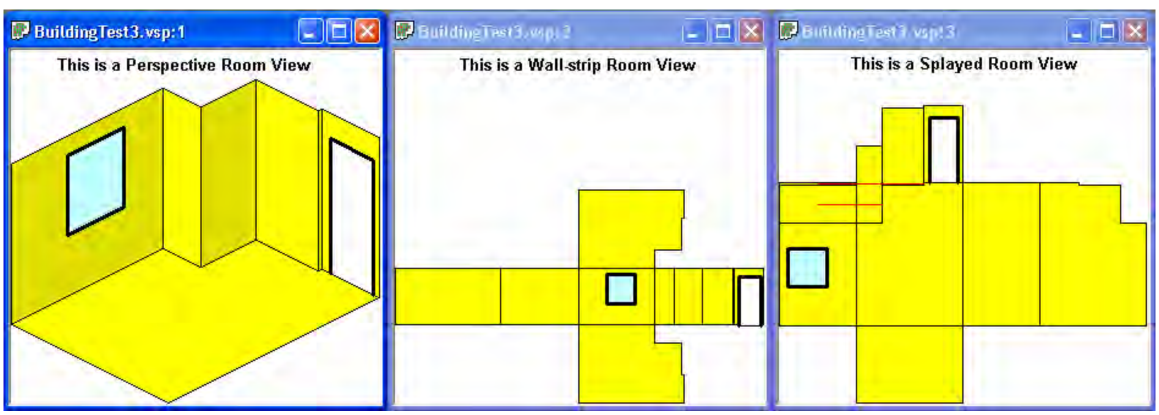


Figure 2.22. Three Perspective Views of a Room

When rooms are defined using pictures or existing maps, the Delineate Rooms (Main Menu item **Room** > **Delineate Rooms**) mode allows the user to create rooms at right angles inside existing map shapes. Delineate Rooms is an on/off toggle switch. While in this mode (you must be in Map View), you can fill up the space inside an irregular-shaped area with individual rectangles. For more information on this tool, consult **Help** > **Help Topics (Contents)** > **Menus** > **Room**> **Delineate Rooms**.

The delineate tool is meant to be used with blank maps and not with rooms drawn with the room drawing tool. If the delineate tool *is* used with rooms drawn with **Room** > **Draw**, and rooms are combined to form irregular shapes (see Section 6.1.3), there may be multiple rooms selected. You can always go to **View** > **Coordinates** to see the rooms selected for sample placement.

Figure 2.23a is an imported CAD drawing of a floor layout with individual rooms delineated using the VSP **Delineate Rooms** tool. Figure 2.23a is the Map View of the room with Room Information displayed (right-click anywhere within the room to display information box). We also used the Main Menu item **Room** > **Insert Annotation** to put the label "Selected Room" on the map. Figure 2.23b is a Room View of the same room with **Perspective View** selected.

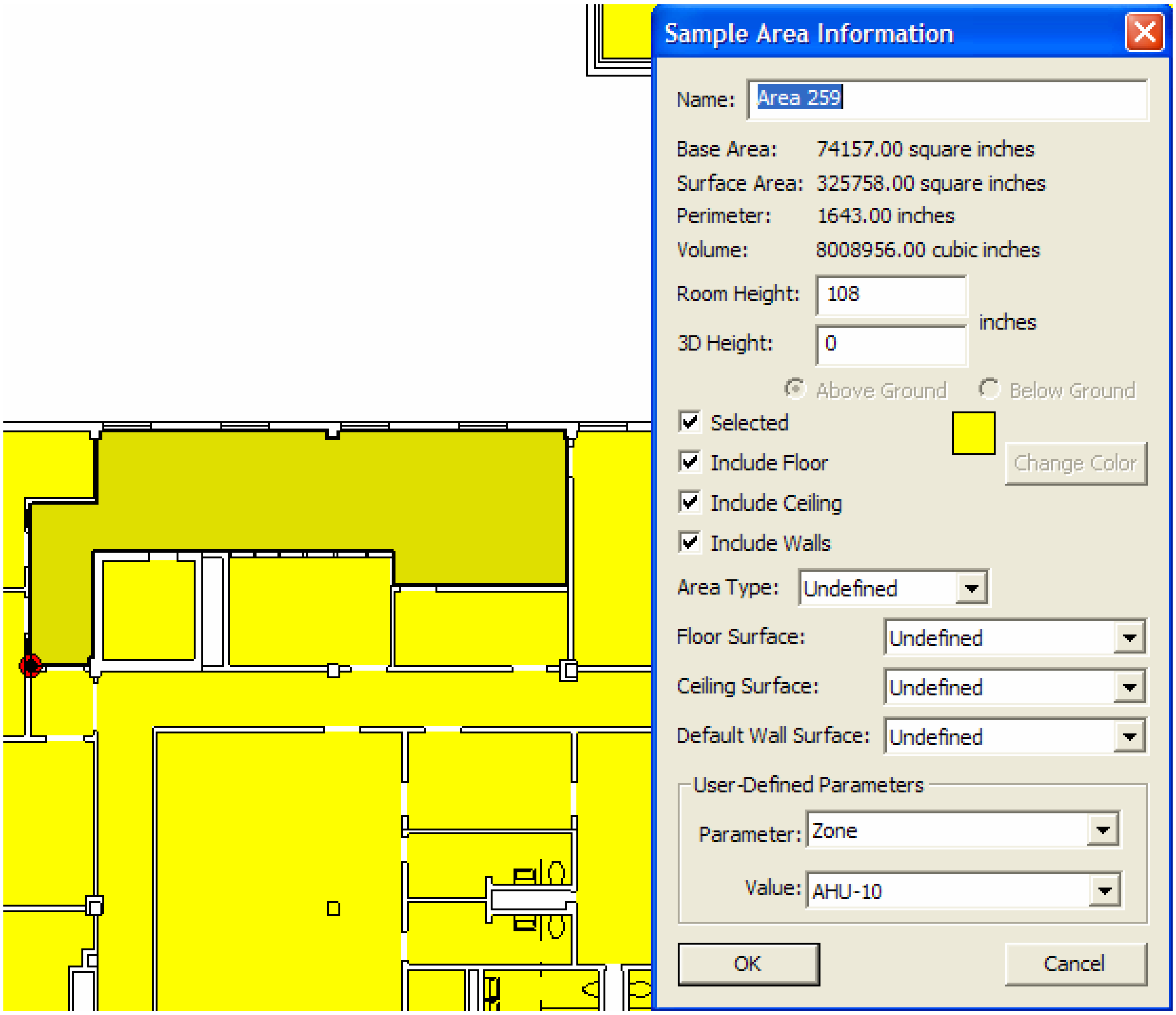


Figure 2.23a. Room in Map View

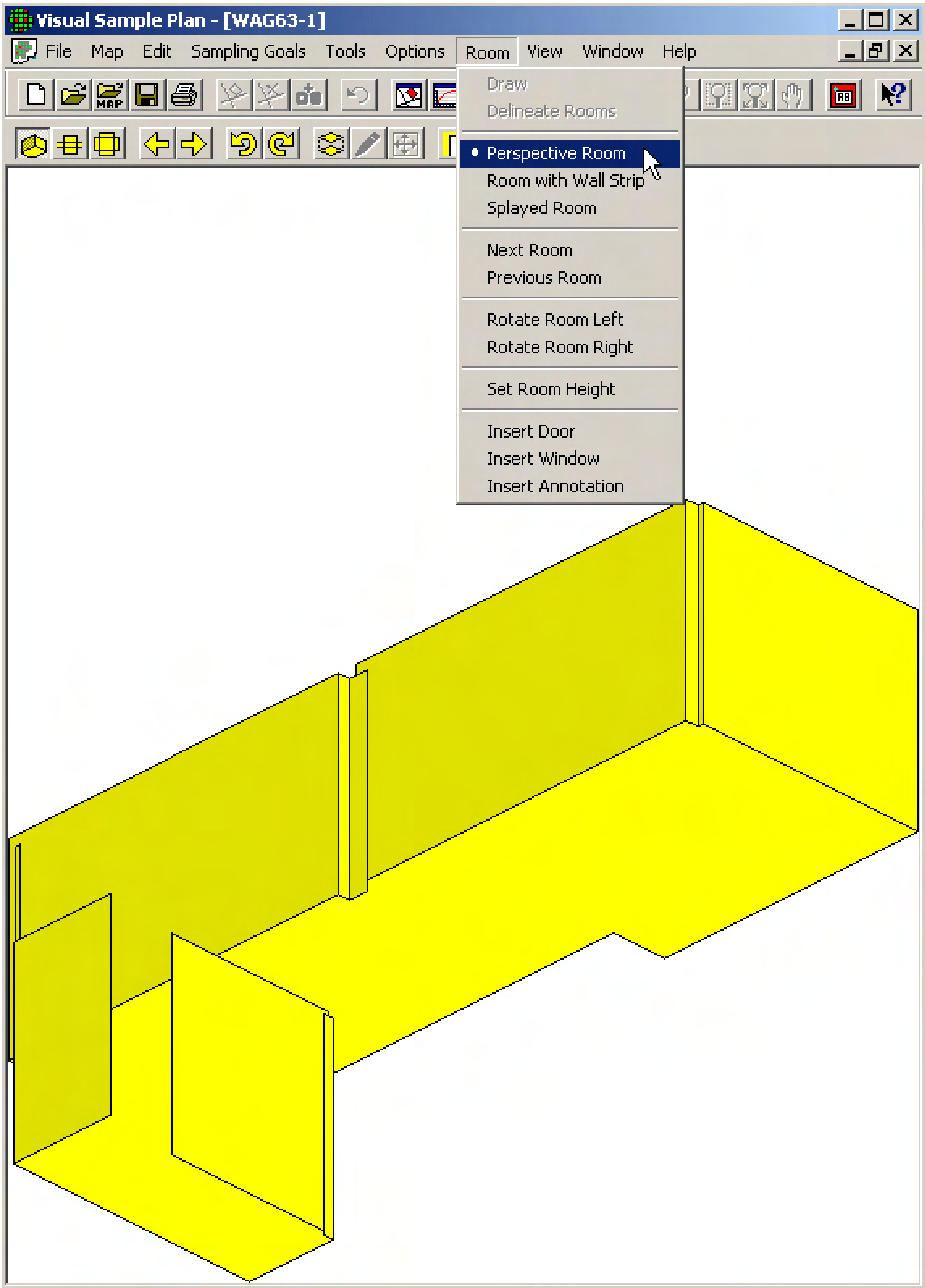


Figure 2.23b. Room in Room View

2.5.2 Extended Room Features

2.5.2.1 Room Objects

VSP has two objects associated with rooms: doors and windows. There are two ways to view these objects: in Map View (see Figure 2.24) and in Room View (see Figure 2.26). Figure 2.24 is another section of the CAD drawing shown in Figure 2.23a. A door in the CAD drawing was defined for VSP. Right-clicking on the Map where the arrow is pointing brings up the **Object Information** dialog box for the Door Object at that location.

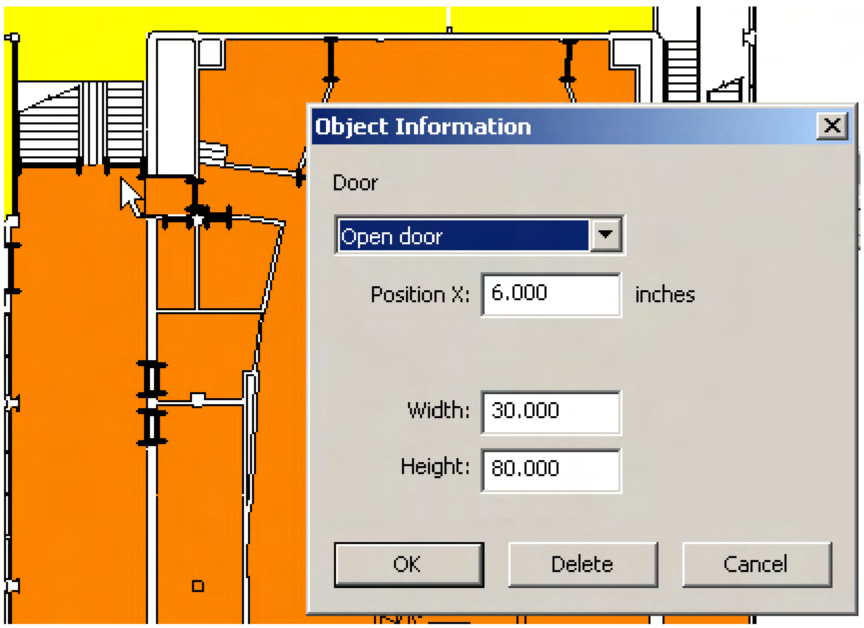


Figure 2.24. Door Object Displayed Using Map View

Doors and windows can be added in Room View using Main Menu item **Room** > **Insert Door/Window** or by clicking on the door or window button on the Room Toolbar. Once added, the properties of the room objects can be viewed by right-clicking on the object, which brings up the **Object Information** dialog box. This is shown for a door in Figure 2.25 and for a window in Figure 2.26.

Note that VSP also has the capability to place a polygon on top of a surface with a different surface type. The polygons are called "Surface Overlays". Surface overlays can be elevated above the floor to represent the top of furniture, such as a table top. Surface overlays are covered in section 6.3.4.

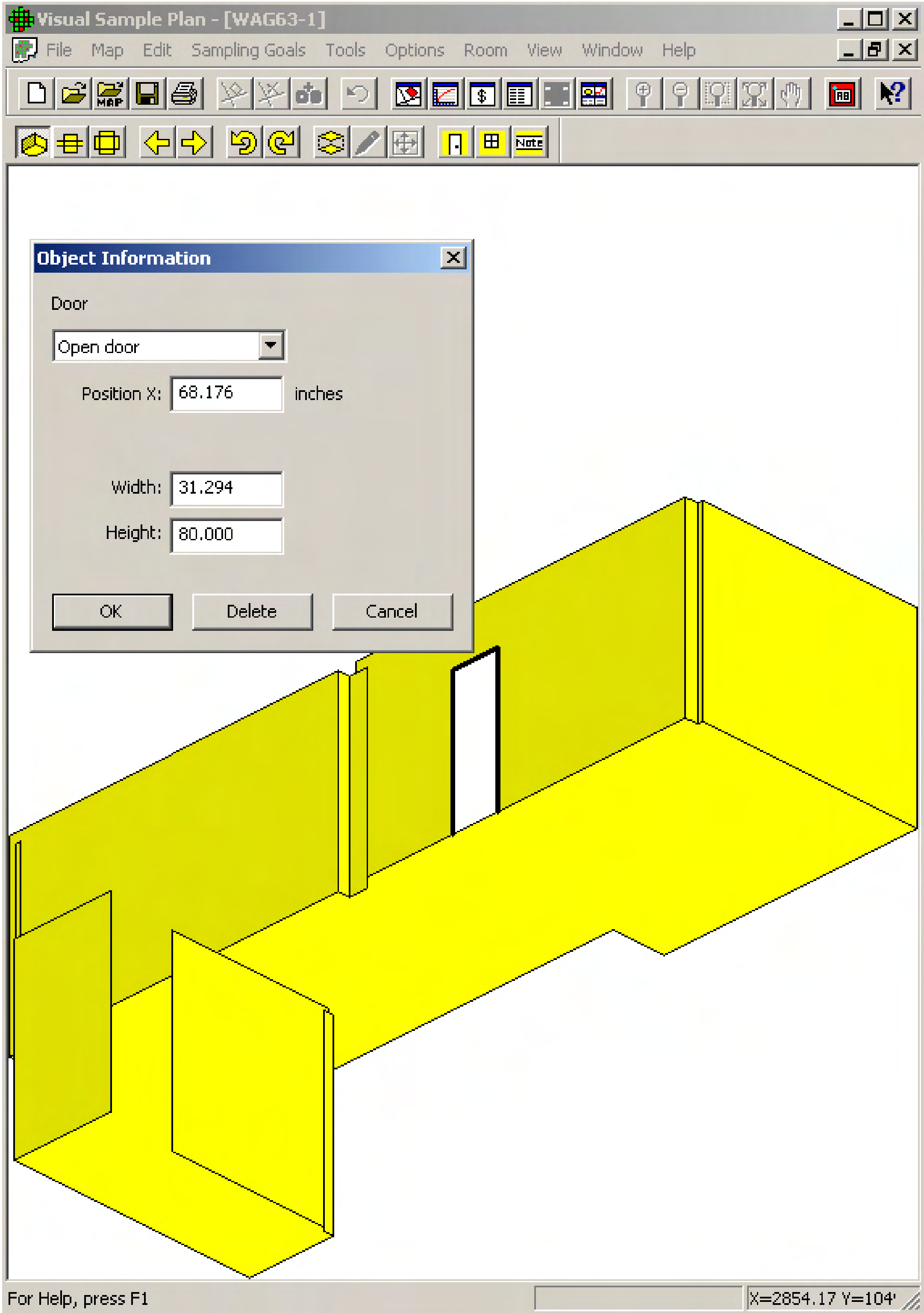


Figure 2.25. Door Room Object with Object Information Dialog Box Displayed

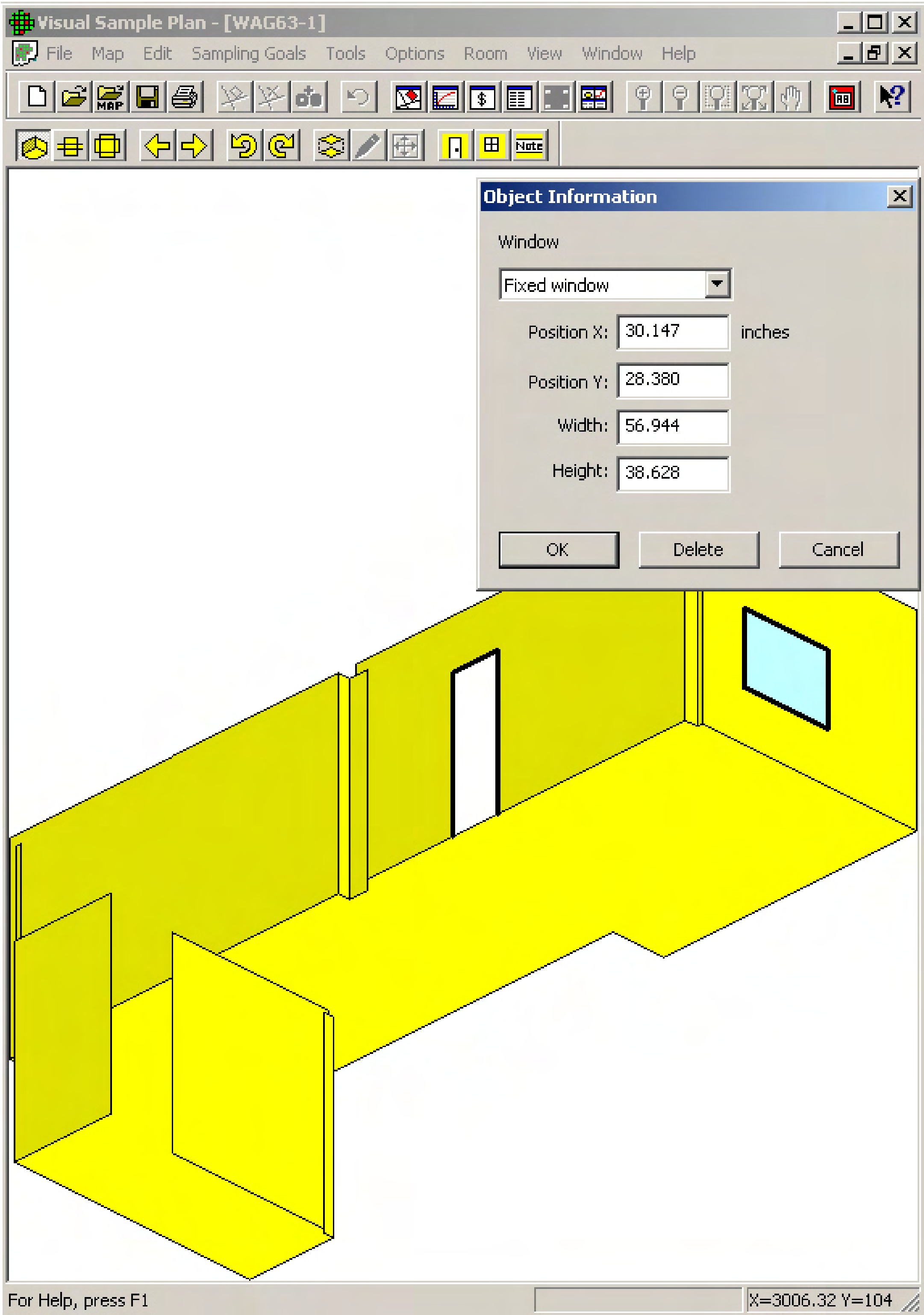


Figure 2.26. Window Room Object with Object Information Dialog Box Displayed

2.5.2.2 Room Parameters

Rooms can have VSP-defined parameters (e.g., Area, Perimeter, Volume, Name) and User-Defined Parameters (e.g., Zone, Class). The User-Defined Parameters are set in the **Sample Area Information** dialog box or with the Main Menu item **Edit > Sample Areas > Set Parameter Values**. This second option is a very powerful tool. Figure 2.24a shows that the room named "Area 259" is in Zone "AHU-10" (i.e., Air Handling Unit 10). All the rooms on AHU 10 are assigned to the same Zone so they are easily identifiable. In another example, rooms that exceed a release criteria could have a logical (yes/no) parameter assigned called "Contaminated", and coded red/green. Note that once a room parameter is set up using Main Menu item **Edit > Sample Areas > User-defined Parameters**, all rooms are given a default value for that parameter. Section 2.3.4 discusses Sample Area Parameters, which also applies to Rooms.

2.5.2.3 Room Color by Parameter

Rooms can be colored automatically based on the value of one of the built-in or user-defined parameters. Once rooms have been defined to VSP, choosing the menu item **Edit > Sample Areas > Color by Value** displays the dialog shown in Figure 2.27. This dialog allows you to choose one of the predefined gradient or discrete color sets and one of the sample area parameters. Certain parameters can also be colored by the logarithm of the value. This dialog also allows the **Color by Value** function to be turned off or on. Use the Help button on the toolbar to find out more information on this tool.

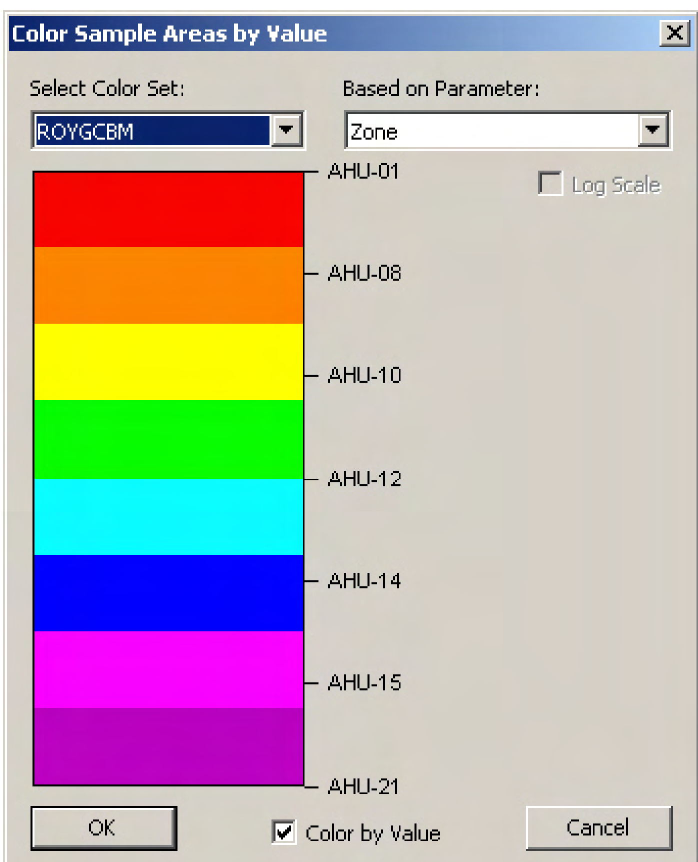


Figure 2.27. Dialog Box for Color Sample Areas by Value

2.5.2.4 Room Order

Clicking the button for **Next Room** from the Room Toolbar, or selecting **Room** > **Next Room** from the Main Menu changes the current room to the next selected room on the map. The current room is indicated by a thick black border and is a slightly darker hue in color-coded rooms. **Previous Room** changes the current room to the previously selected room on the map. The order of room selection is the order of creation. Note that the order for room and sample areas can be changed by the menu command **Edit / Sample Areas / Bring to Front**.

2.5.2.5 Room Rotation

Clicking the button for **Rotate Room Right** from the Room Toolbar, or selecting **Room** > **Rotate Room Right** from the Main Menu rotates the Perspective or Wall-Strip Room View clockwise 90 degrees. **Rotate Room Left** rotates the Perspective or Wall-Strip Room View counter-clockwise 90 degrees.

2.6 Saving a VSP File

No matter how you imported or created a site map or Sample Area for VSP, you can always save the information in VSP's own file format. From the Main Menu, select **File** > **Save Project** As and provide a name for the project. VSP will add the VSP file extension automatically. Alternatively, you can use the **Save** button with the disk icon on the VSP toolbar. After you have created a sampling design as discussed later in this guide, saving your project as a VSP file also will save the input data, cost data, and recommended sample sizes.

2.7 Help

There are several ways to get **Help** in VSP:

- Select **Help** from the top bar of Menu items for help on the Expert Mentor (section 2.7.1), Help Topics (Contents, Index, and Find), and the VSP version or contacts.

- Select the Help button on the toolbar (button to the far right labeled "?") and go to any pull-down menu item. The Help Topic for that menu selection will be displayed.

- Help button at the bottom of some Dialog Boxes and Input and Output Screens. The Help brings up a new screen that contains a technical discussion of the tests, algorithms, and calculations used by VSP to perform the functions referred to on the Input and Output Screens.

VSP is user-friendly and most users find they can run VSP from the guidance and information presented in the various Help functions in VSP.

2.7.1 Expert Mentor

The Expert Mentor dialog provides guidance, recommendations, and warnings to the VSP user to:

- Help prevent inadvertent misuse of VSP

- Help the user understand how VSP works
- Help ensure the number and location of samples obtained using VSP are appropriate

To activate the Expert Mentor, select **Help** > **Expert Mentor**. Figure 2.28 shows the Expert Mentor dialog.

Figure 2.28 Expert Mentor dialog

On the left-hand side of the dialog in Figure 2.28, there are four major Expert Mentor modules. As of VSP version 5.0, two of these modules are implemented in VSP, **Systematic Planning** and **Setting Up VSP Sites and Maps**. To select a module, click on it. These are briefly discussed in Sections 2.7.1.1 and 2.7.1.2. For an in-depth tutorial, refer to the actual modules themselves. The other two modules, **Sampling Design Selection** and **Design Parameter Selection**, are planned and currently in development.

2.7.1.1 Systematic Planning

Systematic Planning is a process based on the scientific method to ensure that the level of effort in planning is sufficient to assure that environmental data collected will be adequate for their intended use.

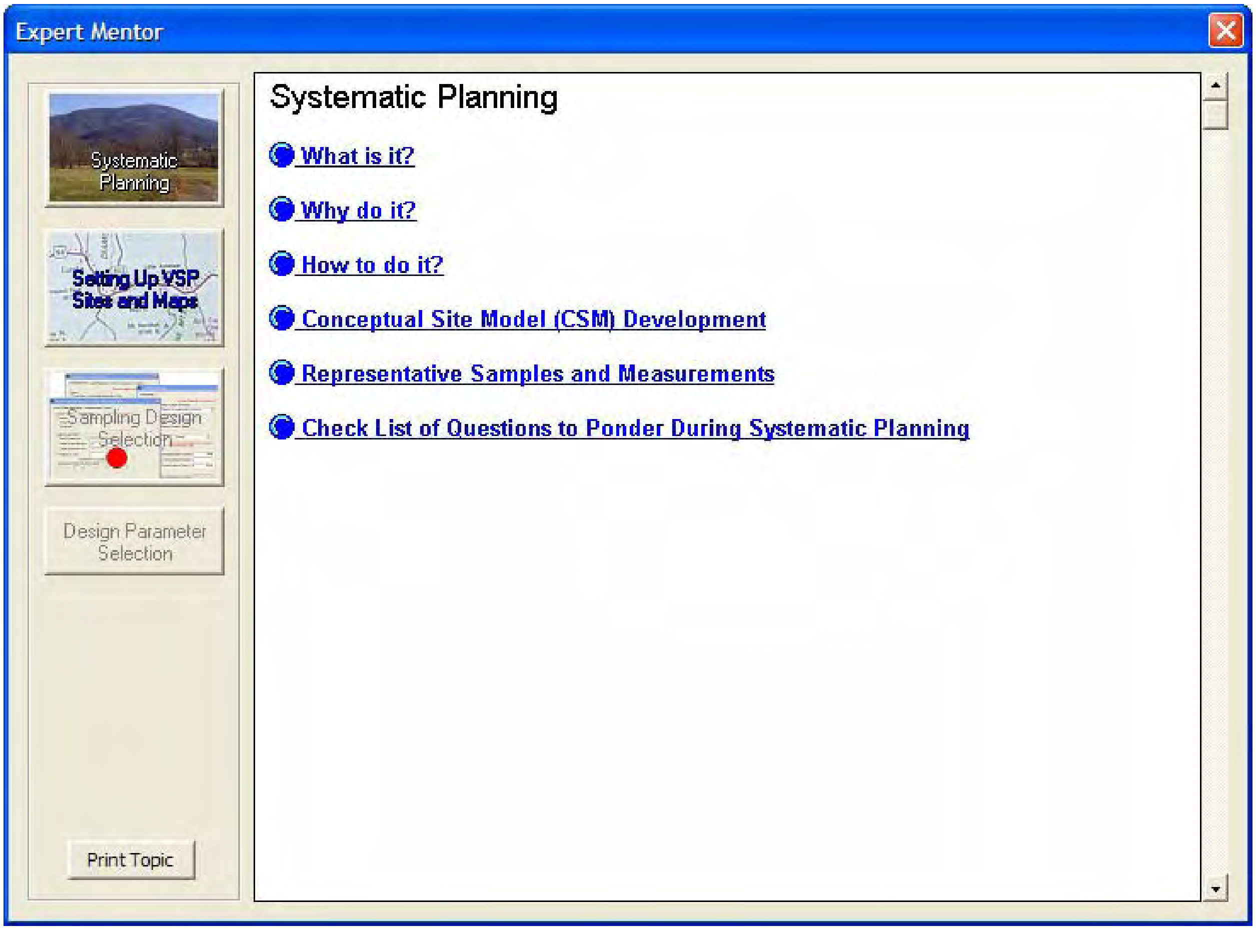


Figure 2.29 Systematic Planning dialog

The dialog for Systematic Planning is shown in Figure 2.29. A number of tutorials can be accessed by clicking on them. These are briefly described below. Note that within each of these topics there are also one to many subtopics which provide additional information and tutorials. To access these subtopics, use the Systematic Planning module in the Expert Mentor.

What is it? This explains what systematic planning is.

Why do it? This provides guidance on avoiding bad data, balancing resources and decision uncertainty, avoiding waste by thinking through why, what, how, and when, assuring VSP is not misused, avoiding bad or inappropriate data, getting the right amount of representative data, and using the right statistic.

How to do it? This describes the DQO (Data Quality Objectives) process and the Triad Approach for modernizing and streamlining sampling, analysis, and data management.

Conceptual Site Model (CSM) Development. Explains how to use a Conceptual Site Model that describes what is known about the site.

Representative Samples and Measurements. Explains what Representative Samples and Measurements are, why they are important, and how to achieve them.

Check List of Questions to Ponder During Systematic Planning. Provides a list of questions to go through to assist in the planning process.

2.7.1.2 Setting Up VSP Sites and Maps

This module explains the process of loading, drawing, and setting up Maps in VSP. The Setting Up VSP Sites and Maps dialog is shown in Figure 2.30. The sections shown in Figure 2.30 are explained below.

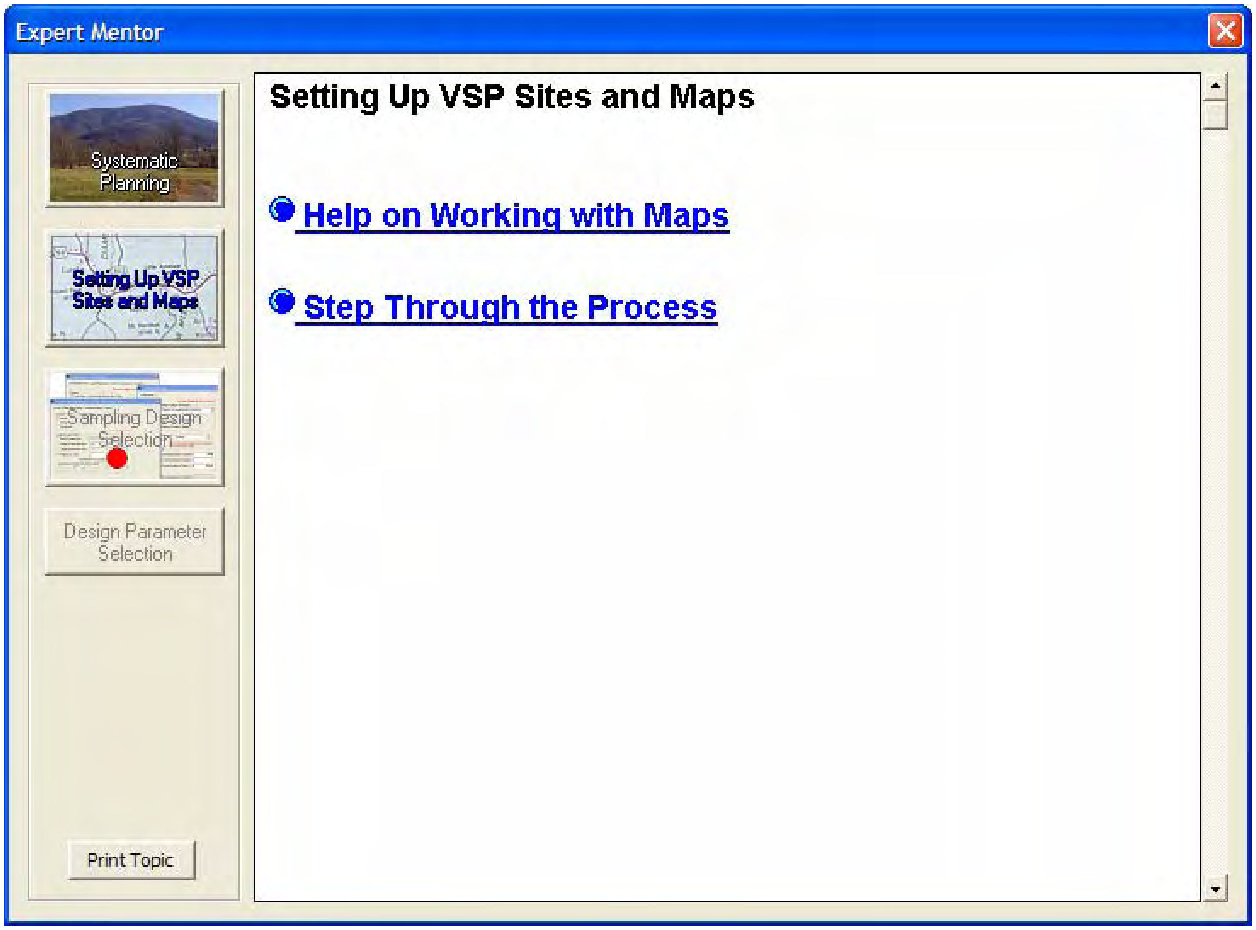


Figure 2.30 Setting up VSP Sites and Maps dialog

Help on Working with Maps. This section explains a number of topics on how to work with maps. Topics include an overview, objects in VSP maps, loading maps from a file, creating a map by drawing, creating a map from coordinates, editing a map, editing a sample area, navigating the map, working with background pictures, and topics on miscellaneous tools, tips, tricks, and traps.

Step Through the Process. This section allows you to step through the process of setting up a site in VSP in a systematic fashion. Clicking on the links actually performs or initiates the actions within VSP. Topics include starting with a blank project, loading and drawing maps, setting map units, creating a sample area, and loading a background picture.

3.0 Sampling Plan Development Within VSP

3.1 Sampling Plan Type Selection

Sampling plan components consist of where to take samples, how many samples to take, what kind of samples (e.g., surface soil, air), and how to take samples and analyze them. We identified the general areas of where to take samples in Section 2.3, **Sample Areas in VSP.** In this section, we discuss where *within the Sampling Area* to locate the samples. We also discuss *how many* samples to take. The kind of samples to take—i.e., soil vs. groundwater, wet vs. dry, surface vs. core,—is determined during Step 3 of the DQO process (Define Inputs) and is not addressed directly in VSP. The Measurement Quality Objectives module in VSP (Section 5.4) deals with how the method selected for analytically measuring the sample relates to other components of the sampling plan.

3.1.1 Defining the Purpose/Goal of Sampling

VSP follows the DQO planning process in directing users in the selection of the components of the sampling plan. The first thing you must do is to select the type of problem for which the current data collection effort will be used to resolve. In VSP, we call this the Sampling Goal. The following types of problems are addressed currently in VSP. Future versions will expand on this list:

Sampling Goal	Description
Compare Average to Fixed Threshold	Calculates number of samples needed to compare a sample mean or median against a predetermined threshold and places them on the map. This is called a one-sample problem
Compare Average to Reference Average	Calculates number of samples needed to compare a sample mean or median against a reference mean or median and places them on the map. This is typically used when a reference area has been selected (i.e., a background area) and the problem is to see if the study area is equal to, or greater than, the reference area. This is called a two-sample problem because the data from two sites are compared to each other
Estimate the Mean	Calculates number of samples needed to estimate the population mean and places them on the map
Construct Confidence Interval on Mean	Calculates number of samples needed to find a confidence interval on a mean and places them on the map
Locating a Hot Spot	Use systematic grid sampling to locate a Hot Spot (i.e., small pockets of contamination).
Find UXO Target Areas	Traverse and detect an elliptical target zone using transect sampling. Calculates spacing for transects. Evaluates post-survey target detection.
Assess Degree of Confidence in UXO Presence	Assess degree of confidence in UXO presence.
Sampling within a Building	Allows sampling within rooms, zones, floors, etc., for various contamination release scenarios and end goals.
Compare Measurements to Threshold	Calculates number of samples needed to determine if contamination is present or if contamination is above or below a specified threshold.
Combined Average and Individual Measurement Criteria	Compares the results of two designs, to see which one requires the most samples to meet its sampling goals.
Establish boundary of Contamination	Determine whether contamination has migrated across the boundary.
Analyze Wells for Redundancy	Analyzes well data measurements and determines the impact of removing redundant wells.
Detect a Trend	Determine whether a trend exists for a measurement of interest

Detect a Change in Trend	(Not yet active)
Compare Proportion to Fixed Threshold	Calculates number of samples needed to compare a proportion to a given proportion and places them on the map
Compare Proportion to Reference Proportion	Calculates number of samples needed to compare two proportions and places them on the map
Estimate the Proportion	Calculates number of samples needed to estimate the population proportion and places them on the map.
Non-statistical sampling approach	Allows samples to be added to the map without the guidance of statistical methods.

This list of sampling goals available now in VSP reflects the targeted interests and specific problems of our current VSP sponsors. Therefore, the available sampling designs within VSP are not an exhaustive list of designs you might find in a commercial statistical sampling package. Future versions will work toward a complete set of sampling design offerings.

VSP lists "Non-statistical sampling approach" under Sampling Goals, but this is not really a goal. Under this category, VSP allows the user to specify a predetermined sample size and locate the samples judgmentally. Because VSP has no way of knowing how the sample size and sample locations were chosen, the sampling approach is considered to be "non-statistical" (i.e., no confidence can be assigned to the conclusions drawn from judgment samples).

To give you an idea of how VSP threads from Sampling Goal to selection of a sampling design, Figure 3.1 shows the sequence of pull-down menus for one of the goals, **Compare Average to a Fixed Threshold.** All endpoints from the Sampling Goal main menu result in a dialog box where the user provides inputs for the specific design selected. VSP allows only certain options and designs (e.g., simple random, systematic) under each goal. This is because VSP contains the algorithms for calculating sample number and locating samples for only certain *goal-assumptions-statistical test or method* sequences. Future versions of VSP will expand on the number and type of algorithms offered.

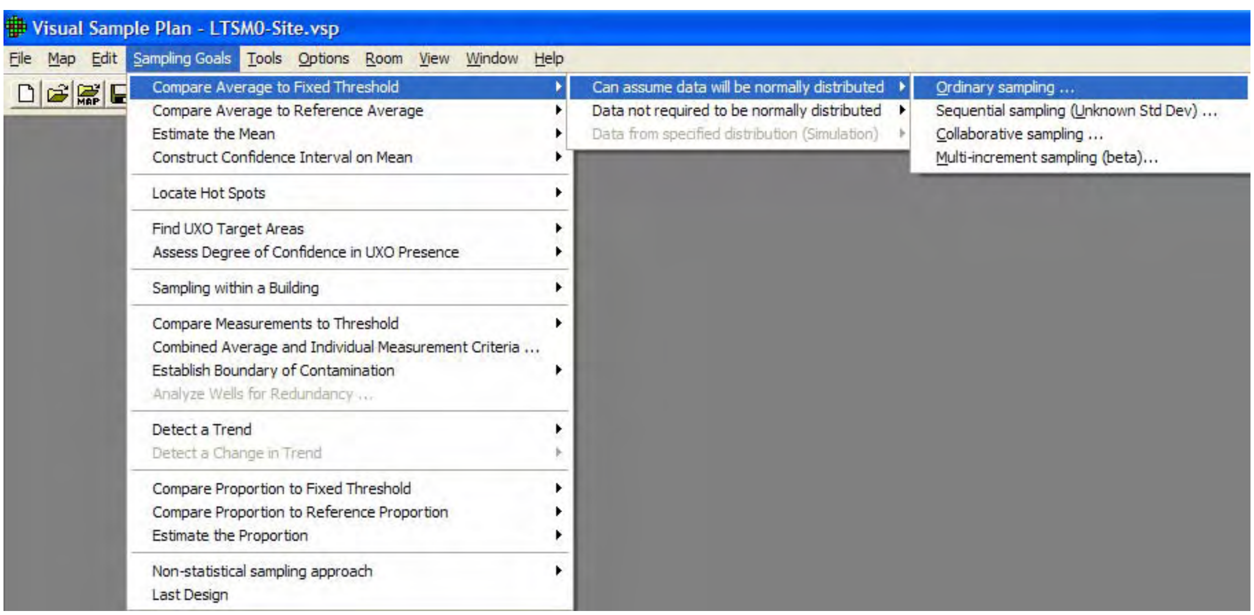


Figure 3.1. Menu Options in VSP for Compare Average to Fixed Threshold

3.1.2 Selecting a Sampling Design

The current release of VSP offers several versions of the software (see Figure 2.1). Each version has a unique set of sampling designs available to the user – except **General (all inclusive) VSP** which contains all the designs. Some of the designs available under each of the Sampling Goal menu items are unique to that goal, other designs are available under multiple goals. Thus, the Sampling Goal you select determines which sampling design(s) will be available to you.

If a user is new to VSP, and is not looking for a specific sample design but rather has a general definition of the problem to be resolved with sample data, a good discussion of how to select a sampling design is in EPA's *Guide for Choosing a Sampling Design for Environmental Data Collection* (EPA 2001) **http://www.epa.gov/quality/qa_docs.html**. See Table 3-1 on pages 23-24 in that source for examples of problem types that one may encounter and suggestions for sampling designs that are relevant for these problem types in particular situations. Another guidance document, *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (EPA 1997) **http://www.epa.gov/radiation/marssim/**, also provides insight into how to select a sample design.

One of the valuable ways to use VSP is to run through the various Goals and see what changes from one Goal to another, what sampling designs are available for each Goal, how designs perform, and what assumptions are required for each design. This trial and error approach is probably the best way to select a design that best fits your regulatory environment, unique site conditions, and goals.

An important point to keep in mind is the linkage between 1) the minimum number of samples that must be collected and where they are located, and 2) how you will analyze the sampling results to calculate summary values (on which you will base your decisions). The user must understand this linkage in order to select the appropriate design. Once the samples are collected and analyzed, the statistical tests and methods assumed in the sample size formulas and design must be used in the analysis phase, Data Quality Assessment (DQA).

Many of the designs in VSP contain a Data Analysis tab and require sample results to be input into VSP so tests can be executed and conclusions drawn based on the results. See Section 5.6 for a discussion of Data Analysis within VSP.

We cannot discuss all the technical background behind the designs here, but the technical documentation for VSP gives sample size formulas used in VSP and provides references. The VSP web site lists the technical documentation available, and allows download of the documents **http://dqo.pnl.gov/VSP/document.htm**. The online help in VSP also provides technical help and references. Finally, the reports that are available within VSP are a good source for definitions, assumptions, sample size formulas, and technical justification for the design selected.

VSP allows both probability-based designs and judgmental sampling:

> Probability-based sampling designs apply sampling theory and involve random selection. An essential feature of a probability-based sample is that each member of the population from which the sample was selected has a known probability of selection. When a probability based design is used, statistical inferences may be made about the sampled population from the data obtained

from the sampled units. Judgmental designs involve the selection of sampling units on the basis of expert knowledge or professional judgment (EPA 2001, pp. 9-10).

The design recommended by VSP depends on the sampling goal selected, assumptions made, and in the case of Ordinary Sampling, user input provided under the **Sample Placement** tab. VSP contains the following two- and three-dimensional designs. With exception to **judgment sampling**, these are probability-based designs.

- Ordinary sampling – two Sample Placement options are available:

    1. **simple random sampling** where sampling locations are selected based on random numbers, which are then mapped to the spatial locations, and

    2. **systematic grid sampling** where sampling locations are selected on a regular pattern (e.g., on a square grid, on a triangular grid, along a line) with the starting location randomly selected. Sampling is done only at the node points of the grid. The grid pattern is selected under **Grid Type**. Figure 3.2 shows the dialog box for making input selections. You can see an example of the grid pattern selected in red to the right of the Grid Type options. You may specify **Random Start** or a fixed start for the initial grid point using the check box next to **Random Start.** Choosing **Random Start** will generate a new random starting location for the first grid location each time the **Apply** button is pushed. Once all selections have been made, press **Apply.**

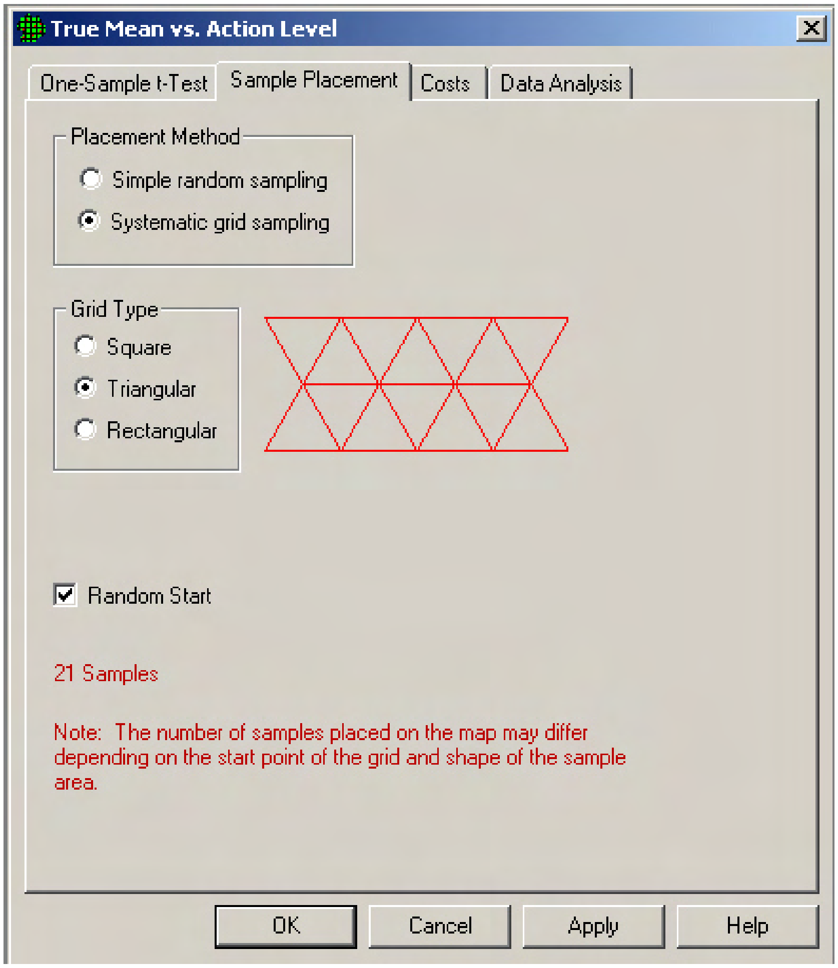


Figure 3.2. Sample Placement Tab for Ordinary Sampling for Selecting Sample Placement Method and Type

- **stratified sampling –** Strata or partitions of an area are made based on a set of criteria, such as homogeneity of contamination. Samples are drawn from each stratum according to a formula that accords more samples to more heterogeneous strata.

- **adaptive cluster sampling –** An initial *n* samples are selected randomly. Additional samples are taken at locations surrounding the initial samples where the measurements exceed some threshold value. Several rounds of sampling may be required. Selection probabilities are used to calculate unbiased estimates to compensate for oversampling in some areas.

- **sequential sampling** - Sequential designs are by their nature iterative, requiring the user to take a few samples (randomly placed) and enter the results into the program before determining whether further sampling is necessary to meet the sampling objectives.

- **collaborative sampling** - The Collaborative Sampling (CS) design , also called "double sampling", uses two measurement techniques to obtain an estimate of the mean – one technique is the regular analysis method (usually more expensive), the other is inexpensive but less accurate. CS is not a type of sampling design but rather method for selecting which samples are analyzed by which measurement method.

- **ranked set sampling –** In this two-phased approach, sets of population units are selected and ranked according to some characteristic or feature of the units that is a good indicator of the relative amount of the variable or contaminant of interest that is present. Only the *m*th ranked unit is chosen from this set and measured. Another set is chosen, and the *m*-1th ranked unit is chosen and measured. This is repeated until the set with the unit ranked first is chosen and measured. The entire process is repeated for *r* cycles. Only the *m* X *r* samples are used to estimate an overall mean.

- **sampling along a swath or transect –** Continuous sampling is done along straight lines (swaths) of a certain width using geophysical sensors capable of continuous detection. Swath patterns can be parallel, square, or rectangular. The goal is to find circular or elliptical targets. This design contains the two elements of traversing the target *and* detecting the target. VSP application is for unexploded ordnance (UXO).

- **sampling along a boundary** - This design places samples along a boundary in segments, combines the samples for a segment, and analyzes each segment to see if contamination has spread beyond the boundary. If contamination has spread, VSP keeps extending the boundary until the sampling goals have been met.

- **judgment sampling –** You simply point and click anywhere in a sampling area. These sampling locations are based on the judgment of the user.

  Because **judgment sampling** is not probability-based, users can bias the sampling results using this method. There is no basis in statistical theory for making confidence statements about conclusions drawn when samples are selected by judgment. However, some problem definitions might call for judgment sampling, such as looking in the most likely spot for evidence of contamination or taking samples at predefined locations. Figure 3.3 shows **judgment sampling** selected in VSP and six sampling locations selected manually.

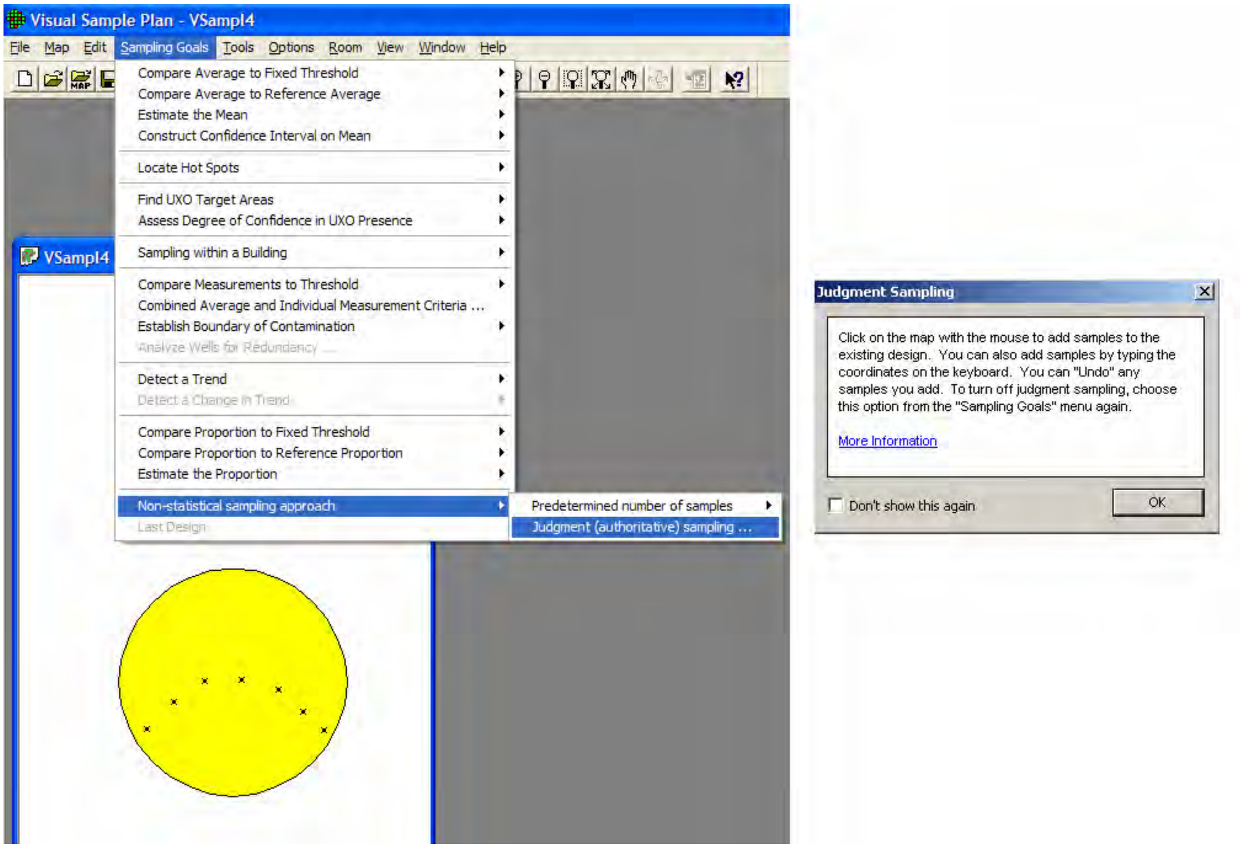


Figure 3.3. Judgment Sampling in VSP

3.2 DQO Inputs and Sample Size

The inputs needed for VSP's sample-size calculations are decided upon during the DQO process. If you have not gone through the DQO process prior to entering this information, you can enter "best guess" values for each of the inputs and observe the resulting computed sample size. New inputs can be tried until a sample size that is feasible and/or within budget is obtained. This iterative method for using VSP is a valuable "what if" tool with which you can see the effect on sample size (and hence costs) of changing DQO inputs. However, be cautioned that all the DQO elements interact and have special meaning within the context of the problem. To be able to defend the sample size that VSP calculates, you must have a defensible basis for each of the inputs. There is no quick way to generate this defense other than going through Steps 1 through 6 of the DQO process.

The core set of DQO inputs that affect sample size for most of the designs are as follows:

- *Null Hypothesis Formulation* – The null hypothesis is the working hypothesis or baseline condition of the environment. There must be convincing evidence in the data to declare the baseline condition to be false. VSP uses a default of "Site is Dirty" as the working hypothesis that must be disproved with convincing evidence from the data.

- *Type I Error Rate (Alpha)* – This is called the *false rejection* rate in EPA's DQO guidance (EPA 2000a). This is the probability of rejecting a true null hypothesis. For the typical hypothesis test in which we assume the survey unit is dirty (above the action level), alpha is the chance a dirty site with a true mean equal to or greater than the Action Level will be released as clean to the public. In general, alpha is the maximum chance, assuming the DQO inputs are true, that a dirty site will be released as clean.

- *Type II Error Rate (Beta)* – This is called the *false acceptance* rate in EPA's DQO guidance. This is the probability of not rejecting (accepting) a false null hypothesis. For the typical hypothesis test in which we assume the survey unit is dirty, beta is the chance a specific clean site will be condemned as dirty. Specifically, beta is the chance that a clean site with a true mean equal to or less than the lower bound of the gray region will be condemned as dirty. In general, beta is the maximum chance, outside the gray region, that a clean site will be condemned as dirty.

- *Width of Gray Region (Delta)* – This is the distance from the Action Level to the outer bound of the gray region. For the typical hypothesis test in which we assume the survey unit is dirty, the gray region can be thought of as a range of true means where we are willing to decide that clean sites are dirty with high probability. Typically, these probabilities are 20% to 95%, i.e., from beta to 1 - alpha. If this region is reduced to a very small range, the sample size grows to be extremely large. Determining a reasonable value for the size of the gray region calls for professional judgment and cost/benefit evaluation.

- *Estimated Sampling Standard Deviation* – This is an estimate of the standard deviation expected between the multiple samples. This estimate could be obtained from previous studies, previous experience with similar sites and contaminants, or expert opinion. Note that this is the square root of the variance. In one form or another, all the designs require some type of user-input as to the variability of contamination expected in the study area. After all, if the area to be sampled was *totally* homogeneous, only one sample would be required to completely characterize the area.

Other inputs are required by some of the designs, and other inputs are required for design parameters other than sample size. For example, the stratified designs require the user to specify the desired number of strata and estimates of proportions or standard deviations for each of the stratum. The UXO (unexploded ordinance) modules use Bayesian methods and require the user to input their *belief* that the study area contains UXO. When simulations are used, as in the post-survey UXO target detection, the user must input assumptions about distribution of scrap or shrapnel in the target areas. In the discussions of the designs, we try to give an explanation of each input required of the user. If you are lost, use the VSP Help functions (See Section 2.7).

Note: The **Help Topics** function in VSP provides a description of each of the designs and its related inputs. You can also select the Help button on the toolbar, put the cursor on any of the designs on the menu and a description of the design and its inputs will appear in a Help window. In addition, pressing the **Help** button at the bottom of each design dialog will bring up a Help window that contains a complete explanation of the design. Finally, on each screen where input is required, highlight an item and press the ***F1*** key for a description of that input item.

The next section contains a discussion of the inputs required by most of the designs available in the current release of VSP. The designs are organized by the Sampling Goal under which they fall. Not all options for all designs are discussed. Common design features (such as Costs, Historical Samples, MQO) that are found in multiple designs will not be discussed individually in this section but can be found in Section 5.0, **Extended Features of VSP.**

3.2.1 Compare Average to a Fixed Threshold

Comparing the average to a fixed threshold is the most common problem confronted by environmental remediation engineers. We present different forms the problem might take and discuss how VSP can be used to address each problem formulation.

We can continue where we left off in Section 2.3.3 with the Millsite.dxf map loaded. We selected a single Sample Area from the site. The Action Level for the contaminant of interest is **6** pCi/g in the top 6 in. of soil. Previous investigations indicate an estimated standard deviation of **2** pCi/g for the contaminant of interest. The null hypothesis for this problem is "Assume Site is Dirty" or H_O: True mean ≥ A.L.

We desire an alpha error rate of **1%** and a beta error rate of **1%.** According to EPA (2000a, pp. 6-10), 1% for both alpha and beta are the most stringent limits on decision errors typically encountered for environmental data. We tentatively decide to set the lower bound of the gray region at **5** pCi/g and decide a **systematic** grid is preferable.

We will use VSP to determine the final width of the gray region and the number of samples required. Assume the fixed cost of planning and validation is $1,000, the field collection cost per sample is $100, and the laboratory analytical cost per sample is $400. We are told to plan on a maximum sampling budget of $20,000.

Case 1: We assume that the population from which we are sampling is approximately normal or that it is well-behaved enough that the Central Limit Theorem of statistics applies. In other words, the distribution of sample means drawn from the population is approximately normally distributed. We also decided that a systematic pattern for sample locations is better than a random pattern because we want complete coverage of the site.

VSP Solution 1: We start by choosing VSP Sampling Goal option of **Compare Average to Fixed Threshold** > **Can assume data will be normally distributed** > **Ordinary Sampling.** For Sample Placement, we select Systematic grid sampling. For Grid Type we select **Triangular** with a **Random Start**. A grouping of the input dialogs is shown in Figure 3.4.

We see that for our inputs, using a one-sample t-test will require taking **90** samples at a cost of **$46,000**. Clearly, we need to relax our error tolerances or request more money.

For the sake of argument, suppose all the stakeholders agree that an alpha error rate of **5%** and a beta error rate of **10%** are acceptable. Figure 3.5 reveals that those changes lead to a significant reduction in the sampling cost, now **$19,000** for n = **36** samples.

Are these new error rates justifiable? Only the specific context of each problem and the professional judgment of those involved can answer that question.

What about the assumption that we will be able to use a parametric test, the one-sample t-test? Unless the population from which we are sampling is quite skewed, our new sample size of n = **36** is probably large

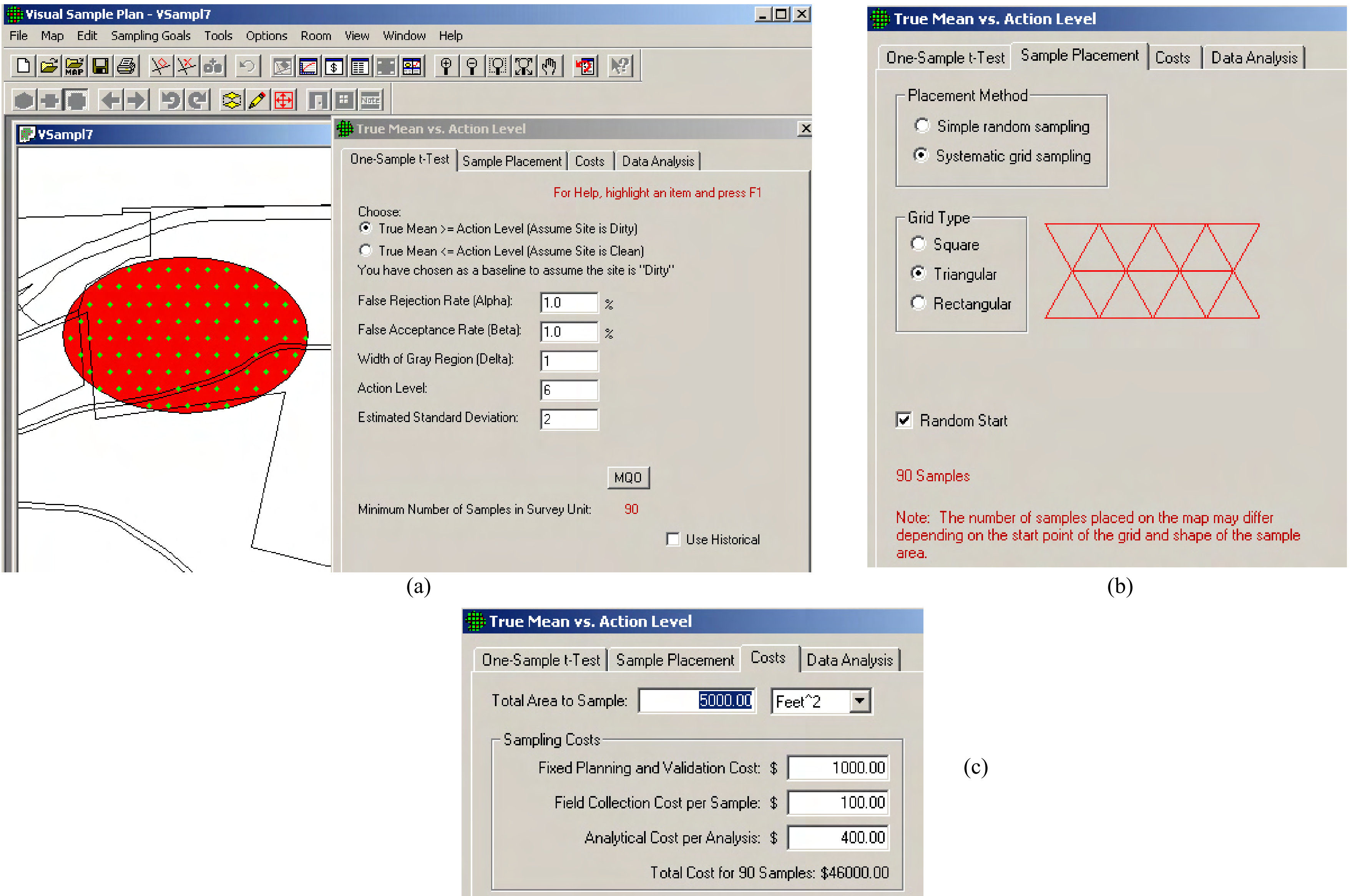


Figure 3.4. Input Boxes for Case 1 with Original Error Rates

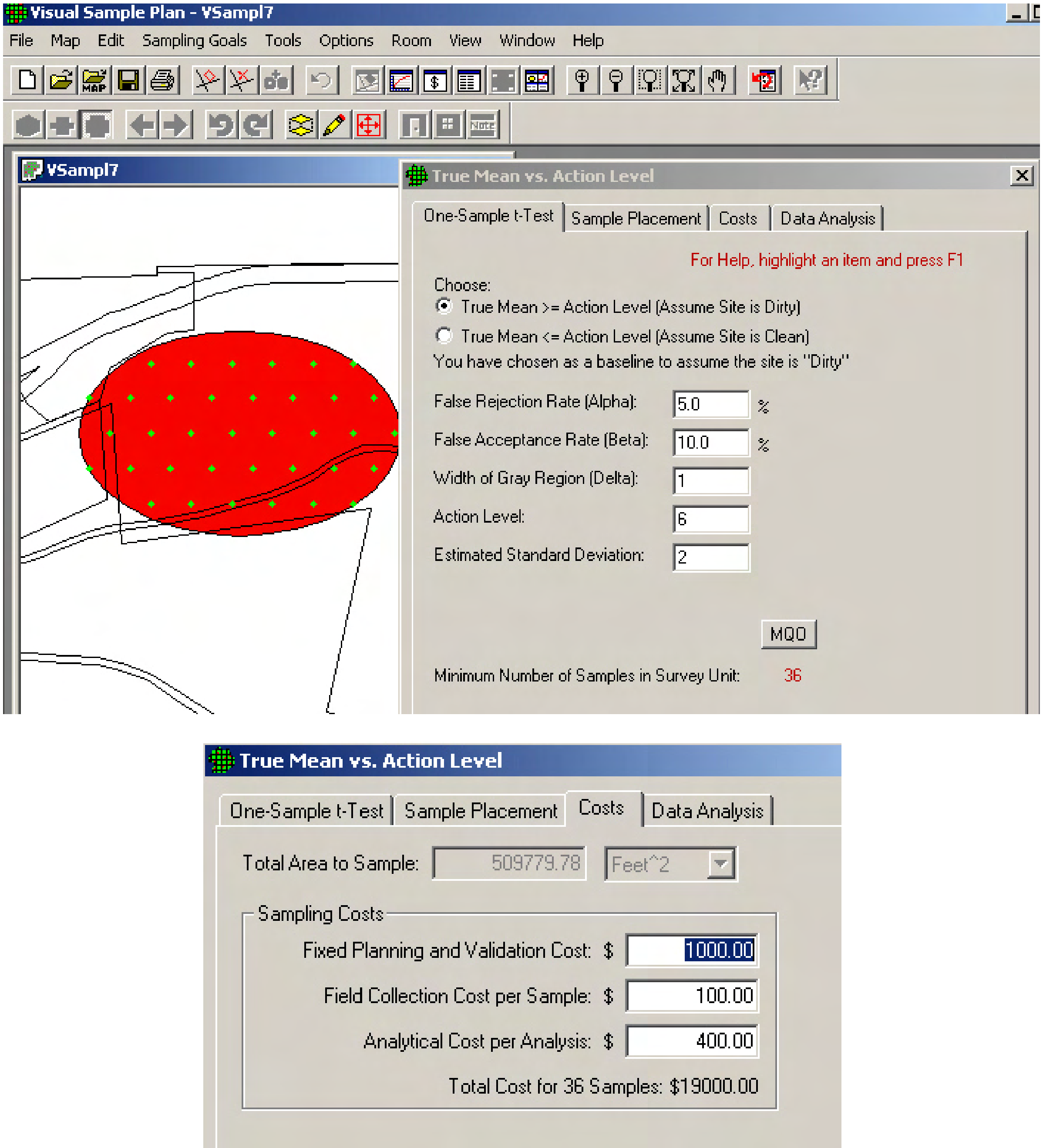


Figure 3.5. Input Boxes for Case 1 with Increased Error Rates

enough to justify using a parametric test. Of course, once we take the data, we will need to justify our assumptions as pointed out in *Guidance for Data Quality Assessment Practical Methods for Data Analysis* (EPA 2000b, pp. 3-5).

Case 2: We now decide that we want to look at designs that may offer us cost savings over the systematic design just presented. We have methods available for collecting and analyzing samples in the field making quick turnaround possible. We want to be efficient and cost-effective and take only enough samples to confidently say whether our site is clean or dirty. After all, if our first several samples exhibit levels of contamination so high that there is no possible scenario for the average to be less than a threshold, why continue to take more samples? We can make a decision right now that the site needs to be remediated. Sequential designs, and the tests associated with them, take previous sampling results into account and provide rules specifying when sampling can stop and a decision can be made.

VSP Solution 2a: From VSP's main menu, select Sampling Goal of **Compare Average to a Fixed Threshold > Can assume data will be normally distributed > Sequential Sampling (Unknown Std Dev).** The dialog box in Figure 3.6 appears. We begin by entering the DQO parameters for Alpha, Beta, Action Level, etc. Next, enter the Number of Samples Per Round, shown here as **3**. This parameter indicates how many samples you want to take each time you mobilize into the field. Each time you press the Apply button, VSP places a pattern of this many sampling locations on the map. In the first round, VSP places at least 10 samples to get an estimate of the standard deviation.

When you close this design dialog, this pattern of sampling locations is locked or "frozen." In Figure 3.6, we see the results of pressing **Apply,** and ten locations are placed on the Map labeled "Seq-1, Seq-2, etc.".

You must now exit this dialog (close the display by clicking the X in the upper right-hand corner of the display), go out and take the samples, and analyze them. Once the sample results are available, re-open the

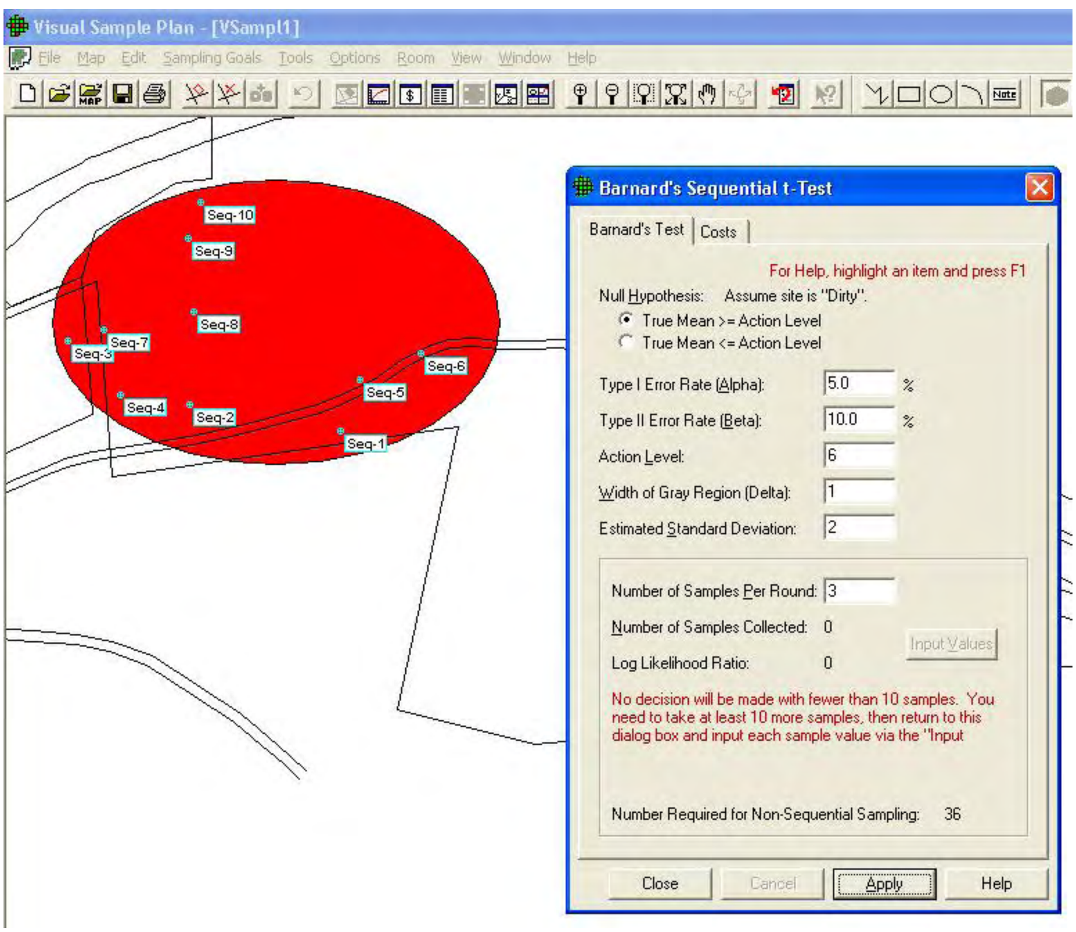


Figure 3.6. Dialog for Sequential Sampling (Standard Deviation Known) and Ten Locations Placed on the Map

Barnard's Sequential t-Test design dialog box. The easiest way to re-open a sampling design, is to use the menu item: **Sampling Goals > Last Design** or click the **Last Design** button on the main toolbar.

In Figure 3.7, you now see the **Number of Samples Collected** as **10.** Press the **Input Values** button and enter the measurement values for those ten samples into the grid on the data input dialog. We enter these values as **5, 8, 6, 7, 5, 4, 8, 4, 7 and 5.** Press the **OK** button and VSP returns to the original SPRT dialog box. We now see that VSP calculated a mean of **5.9** and a standard deviation of **1.52** for the values we entered. VSP cannot accept or reject the null hypothesis with ten or fewer samples and suggests that up to **2** additional samples may be needed to make a decision. VSP asks you to take **3** more samples. Press the **Apply** button to place **3** more samples on the map.

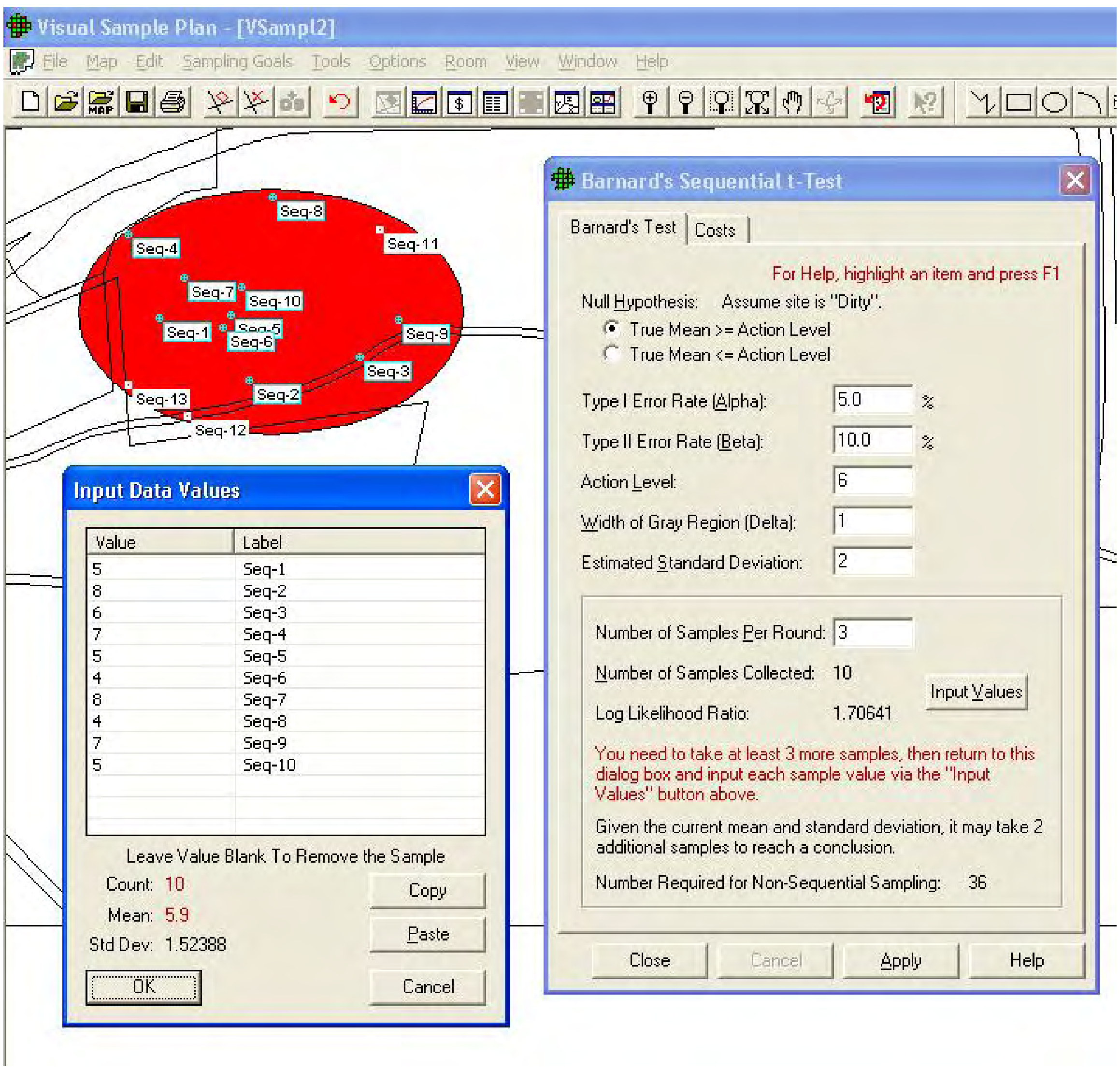


Figure 3.7. Data Input Dialog for Sequential Probability Ratio Test and Results from First Round of Sampling. Map View is shown in background.

Switching over to the Graph View in Figure 3.8, we can see that in order to accept the null hypothesis that the site is dirty we need to take more than 10 samples. The open circles show the test statistic as the data are collected. The last 3 samples that appear on the graph can be ignored, since we haven't yet entered data for them.

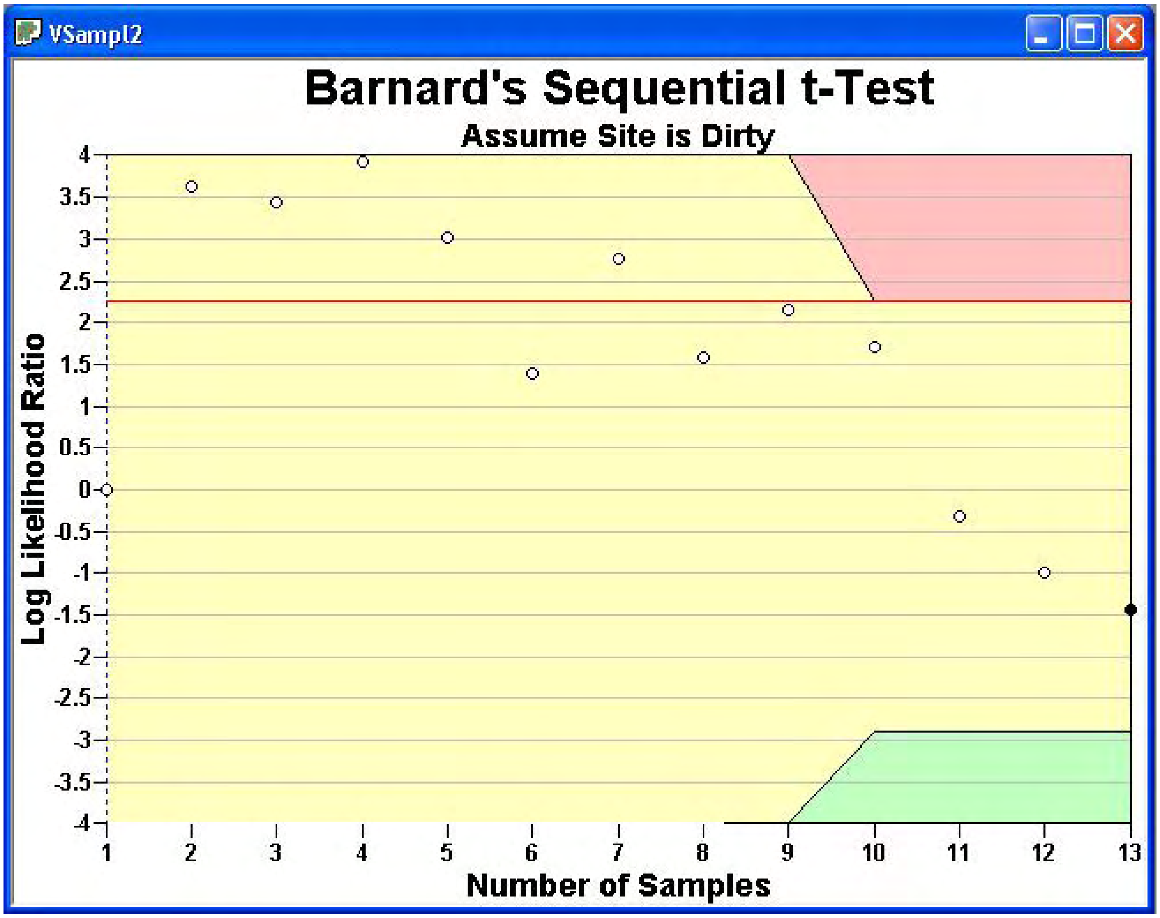


Figure 3.8. Graph View of Sequential Sampling

We take the next set of three samples (by closing the Barnard's dialog, re-opening it, and press the **Input Values** button) and enter the values **6, 7, and 8.** VSP now tells us that we can **Accept the Null Hypothesis** and conclude the site is dirty.

VSP Solution 2b. We have one other option for more cost-efficient sampling – reduce the analytic laboratory costs by taking advantage of measurement equipment that may be less accurate, but is less expensive. If we can still meet our DQOs (error levels, width of grey region) taking advantage of the less expensive equipment, we will save money.

It works like this: At '*n*' field locations selected using simple random sampling or grid sampling, the inexpensive analysis method is used. Then, for some of the '*n*' locations, the expensive analysis method is also conducted (n_E). The data from these two analysis methods are used to estimate the mean and the standard error (SE: the standard deviation of the estimated mean). The method of estimating the mean and SE assumes there is a linear relationship between the inexpensive and expensive analysis methods. If the linear correlation between the two methods is sufficiently high (close to 1), and if the cost of the inexpensive analysis method is sufficiently less than that of the expensive analysis method, then CS is expected to be more cost effective at estimating the population mean than if the entire measurement budget was spent on obtaining only expensive analysis results at field locations selected using simple random sampling or grid sampling.

If **Collaborative Sampling** is chosen for the Sampling Goal of **Compare Average to a Fixed Threshold** the dialog box for input (with the **CS** tab selected) , and the resulting **Map View** of the applied CS samples on the Millsite.dxf map are all shown in Figure 3.9.

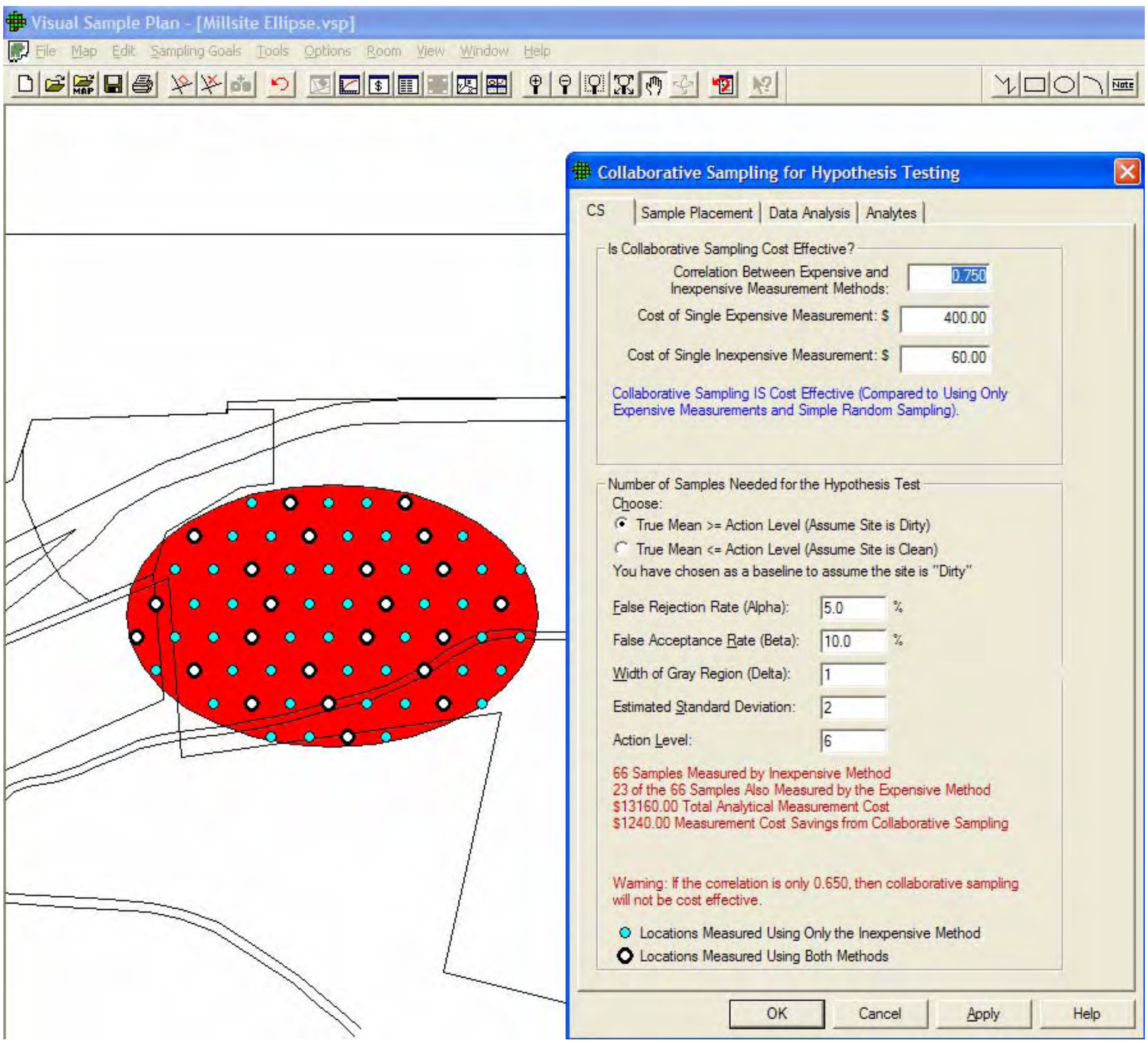


Figure 3.9. Dialog Box for Collaborative Sampling and Map View of Applied CS Samples

The first set of inputs requested in the **Data Input Dialog Box** for CS are those needed to determine whether CS sampling is more cost effective than using only expensive measurements and simple random sampling. The first input required is the correlation coefficient between expensive and inexpensive measurements computed on the same set of samples. This is determined from data in prior studies or in a pilot study. The next two inputs are the cost estimates: the cost per unit of making a single expensive measurement, including the cost of sample collection, handling, preparation and measurement; and the cost per unit of making a single inexpensive measurement, including finding the field location and conducting the inexpensive analysis method.

The next set of inputs comprises the DQOs for the problem. Notice that these are the same inputs we used for Case 1 with increased error rates (see Figure 3.5) when VSP calculated a required sample size of 36. If all those 36 samples were analyzed with the expensive method, the total cost would be 36 x $400 = $14,400. However, if we use CS and the same DQOs, VSP calculates we need to take 66 samples measured by the inexpensive method, and 23 of those 66 samples measured by the expensive method. This costs a total of 66 x $60 = 3960 plus 23 x $400 = $9200 for a total of $13,160. This represents a $1,240 cost savings over the $14,400 we were going to spend. And the best part is we can achieve this cost savings and still meet our required error rates (i.e., the stated DQOs). Note: If VSP determined that CS was not cost effective, it would not have computed the two samples n and n_E (66 and 23 samples, respectively) and reported only the number of samples that should be collected and analyzed using only the expensive method (36 samples).

Once we hit the Apply button at the bottom of the Dialog Box, VSP places all 66 samples on the Sample Area on the map. VSP color codes those sample locations where both methods should be used vs. the sample locations where just the inexpensive measurement method should be used. The applied color-coded samples are shown in the **Map View** insert in Figure 3.9.

We now exit the Dialog Box by clicking on the X in the upper right-hand corner of the display. We take our samples, use the appropriate measurement method, and return to the sample Dialog Box to input the results from the lab. This time we select the tab labeled **Data Analysis** when we enter the Dialog Box, and then the **Data Entry** tab. The data values can be entered by typing them into this input screen, or by importing the data from a file such as an Excel spreadsheet (see Section 2.4.1 Importing Samples). Figure 3.10a shows the Dialog Box for entering data.

Note that the values we entered result in a Standard Deviation of 2.24 – we estimated 2, and the two sets of sample values have a correlation of .769 – we estimated .75. We are well above the correlation limit of .650 in order for collaborative sampling to be cost effective. If we bring up the Graph View in a second window (**View** > **Graph**), we see that VSP has taken the data values we input and plotted the expensive measurements versus the inexpensive measurements. This plot can be used to assess whether the assumption of a linear relationship between the expensive and inexpensive measurements required for the use of CS is reasonable. Note that the calculated Rho = .769 (the correlation coefficient) is listed at the top of the graph. The regression line is the solid red line through the points. The dashed blue line represents the computed mean (x_{cs}). The horizontal red line represents the threshold value (Action Level). The bottom edge of the hashed red region represents the computed mean value below which the null hypothesis can be rejected.

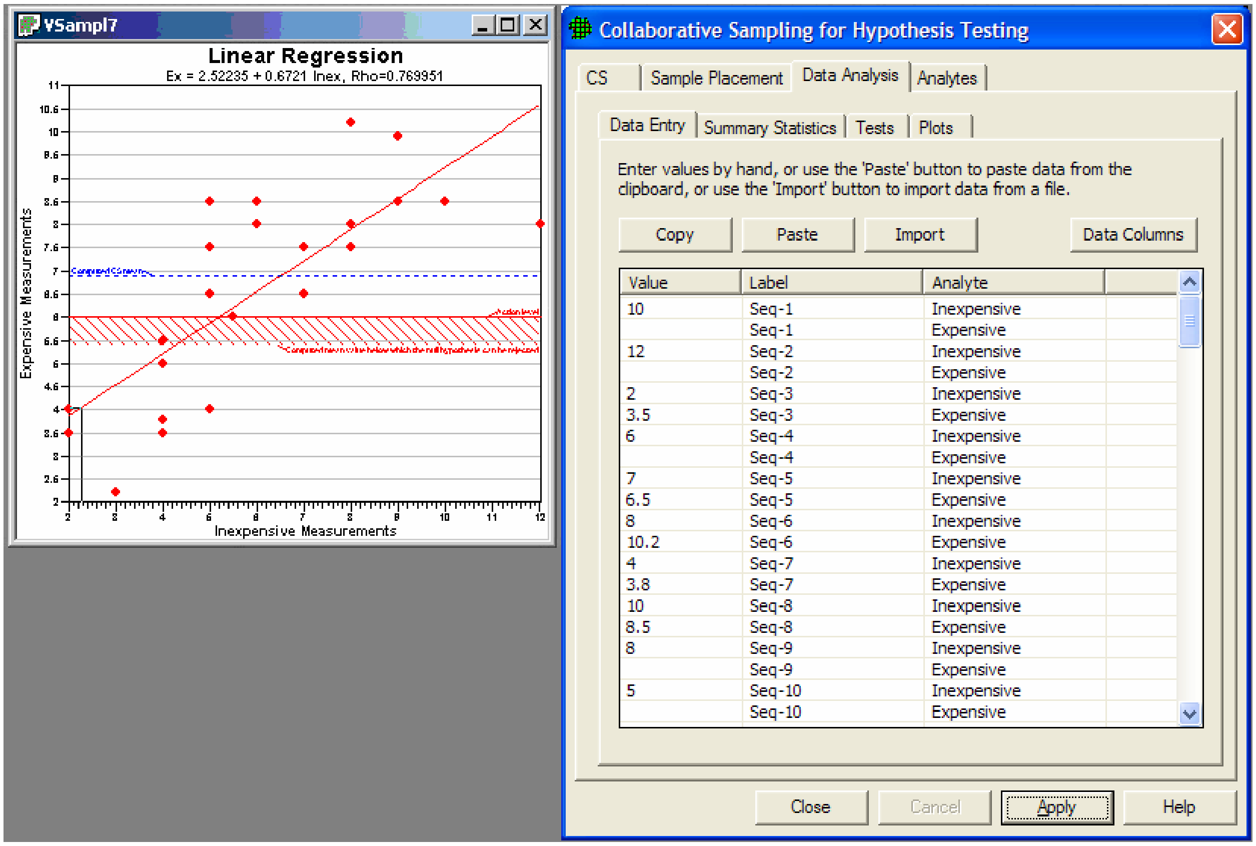


Figure 3.10a. Dialog Box for Entering CS Data Values and Graph View Showing where Data Values Fall on a Linear Regression Line

VSP reports that based on the data values input, we can Accept the Null Hypothesis: Assume the Site is Dirty.

If we had chosen **Simple Random Sampling** rather than **Systematic Grid Sampling** on the Sample Placement tab, all the sample sizes would have been the same. The only difference would have been that the samples would have been placed on the Map in a grid pattern rather than randomly.

Case 3: We do *not* wish to assume that the population from which we are sampling is approximately normal.

VSP Solution 3a: The purpose of a MARSSIM sign test **(Compare Average to Fixed Threshold > Data not required to be normally distributed > Ordinary Sampling – No distributional assumption (MARSSIM)** is to test a hypothesis involving the true mean or median of a population against an Action Level. Using this test for the mean assumes the distribution of the target population *is* symmetrical. When the distribution of the target population is symmetrical, the mean and the median are the same. When the distribution is not symmetrical, the Sign test is a true test for the median, and an approximate test for the mean. The appropriate use of the Sign Test for final status surveys is discussed in Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (EPA 2000). This document is currently available at **http://www.epa.gov/radiation/marssim/**. The input for the MARSSIM Sign Test is shown in Figure 3.10b.

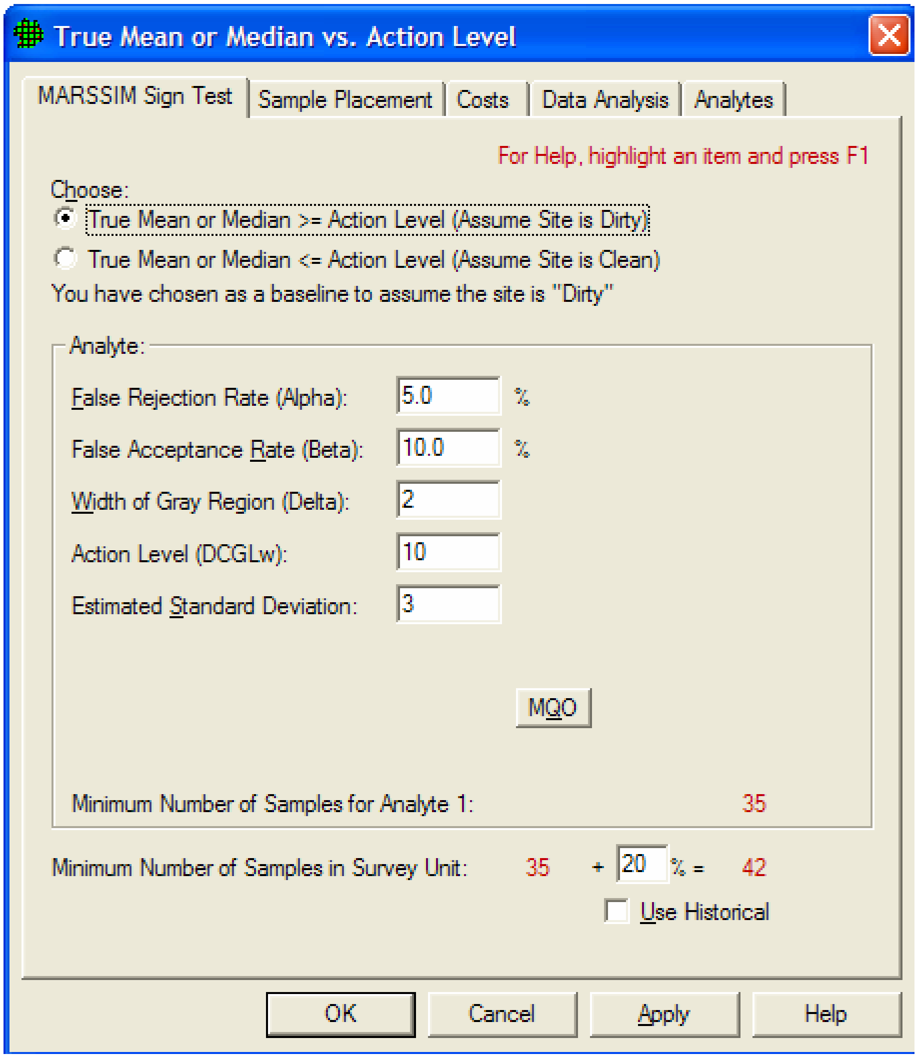


Figure 3.10b. Dialog Box for the MARSSIM Sign Test

VSP Solution 3b: We start by choosing VSP option **Compare Average to Fixed Threshold > Data not required to be normally distributed > Ordinary sampling of symmetric distribution**. Note that using this test for the mean assumes the distribution of the target population is symmetrical. A grouping of the input dialogs is shown in Figure 3.10c.

For our inputs, and assuming that we will use a nonparametric Wilcoxon Signed Ranks test to analyze our data, VSP indicates that we are required to take 42 samples at a cost of $22,000. This is $3,000 more than the previous parametric case, given the same input parameters. Is the choice of a nonparametric test worth the extra $3,000 in sampling costs beyond what was required for the parametric one-sample t-test? VSP does not address that kind of question. Professional judgment is needed. You must make the decision based on the best available data, the consequences of decision errors, and legal and ethical considerations. If little pre-existing information is available, a pilot study to gain a better understanding of the characteristics of the population may be indicated, since a symmetric distribution of the target population is assumed.

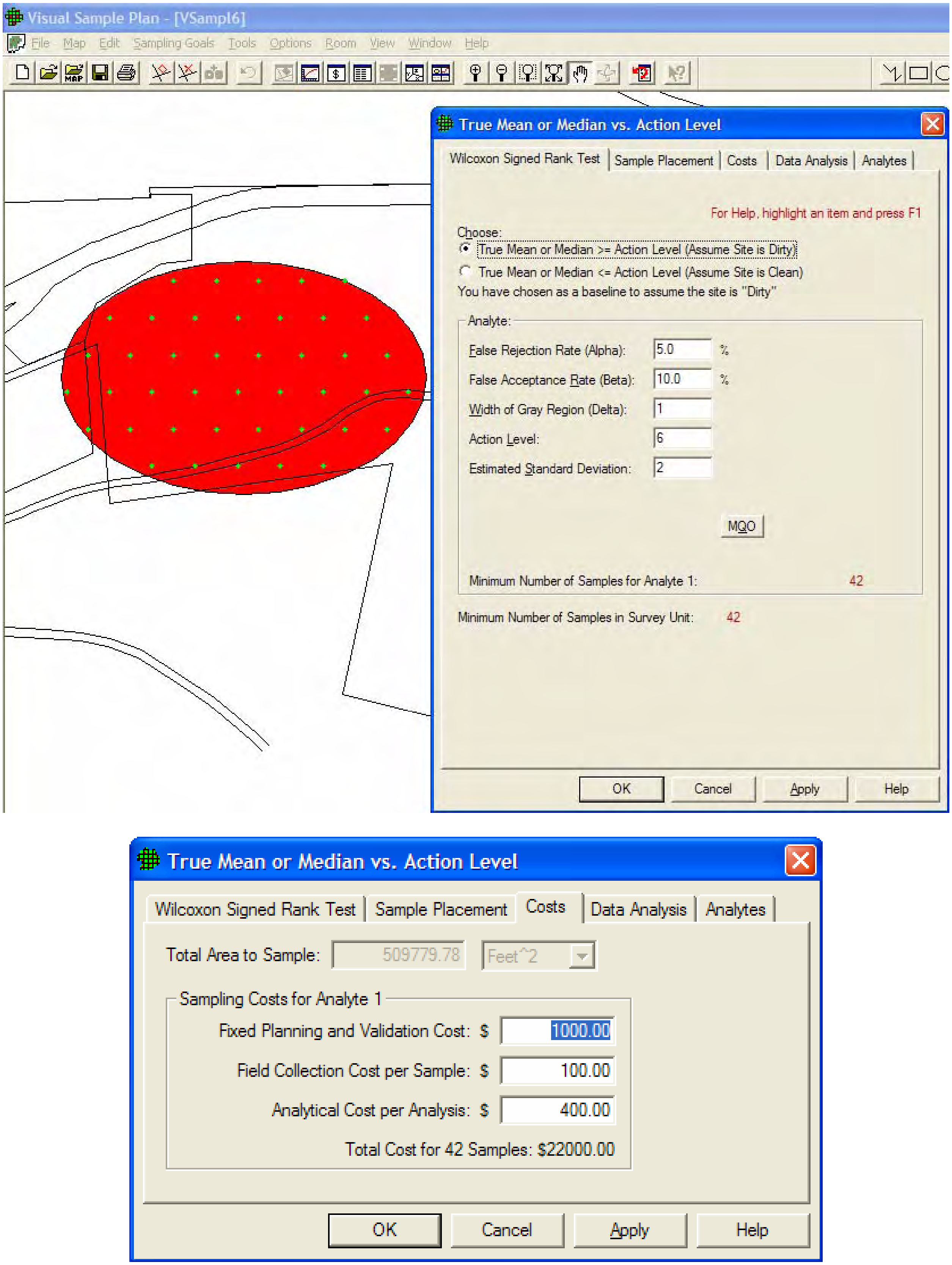


Figure 3.10c. Input Dialog for Wilcoxon Signed Rank Test

3.2.2 Compare Average to Reference Average

We again start with the Millsite.dxf map from Section 2.3.3 with a single Sample Area defined. The Action Level for the contaminant of interest is **5** pCi/g above background in the top 6 in. of soil. Background is found by sampling an appropriate reference area. Previous investigations indicate an estimated standard deviation of **2** pCi/g for the contaminant of interest. The null hypothesis for this problem is “Assume Site is Dirty” or H_O: Difference of True Means ≥ Action Level. In other words, the parameter of interest for this test is the *difference* of means, not an individual mean as was the case in the one-sample t-test.

We desire an alpha error rate of **1%** and a beta error rate of **1%.** We tentatively decide to set the lower bound of the gray region to **4** pCi/g above background, i.e., a *difference* of means of 4 pCi/g. Using VSP, we will determine the final width of the gray region and the number of samples required.

Assume that the fixed planning and validation cost is $1,000 for each area, and the field collection and measurement cost per sample is $100, and the laboratory analytical cost per sample is $0 because we are able to justify the use of field measurements. We are told to plan on a maximum sampling budget of **$20,000** for *both* the Reference Area and the Study Area.

Case 4: We assume that the populations we are sampling are approximately normal or that they are well--behaved enough so that the Central Limit Theorem of statistics applies. In other words, the distributions of sample means drawn from the two populations are approximately normally distributed. If that is the case, the distribution of the differences also will be approximately normally distributed. We also assume the standard deviations of both populations are approximately equal. In addition, we determine that a systematic grid sampling scheme is preferable.

VSP Solution 4a: We start by choosing from the main menu: **Sampling Goals > Compare Average to Reference Average > Can assume data will be normally distributed > Equal sample sizes**. A grouping of the input dialogs is shown in Figure 3.11.

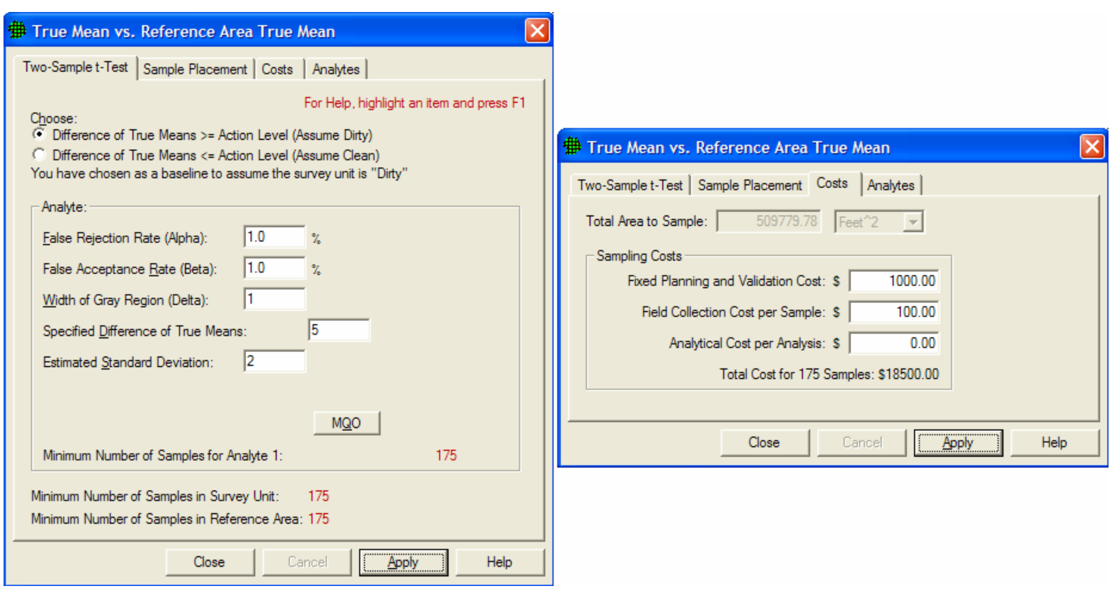


Figure 3.10. Input Dialog for Case 4 with Original Error Rates

We see that for our inputs, using a two-sample t-test will require taking **175** field samples in the Sample Area at a cost of **$18,500**. The sampling cost for the Reference Area also will be $18,500. The combined sampling cost of **$37,000** is significantly beyond our budget of $20,000. What will be the result if we relax the error rates somewhat?

In Figure 3.12a, by increasing both the alpha error rate and the beta error rate to **5%,** the sampling cost for one area has decreased to **$9,800** based on n = **88** field samples. Thus, the new combined cost of **$19,700** achieves our goal of no more than $20,000.

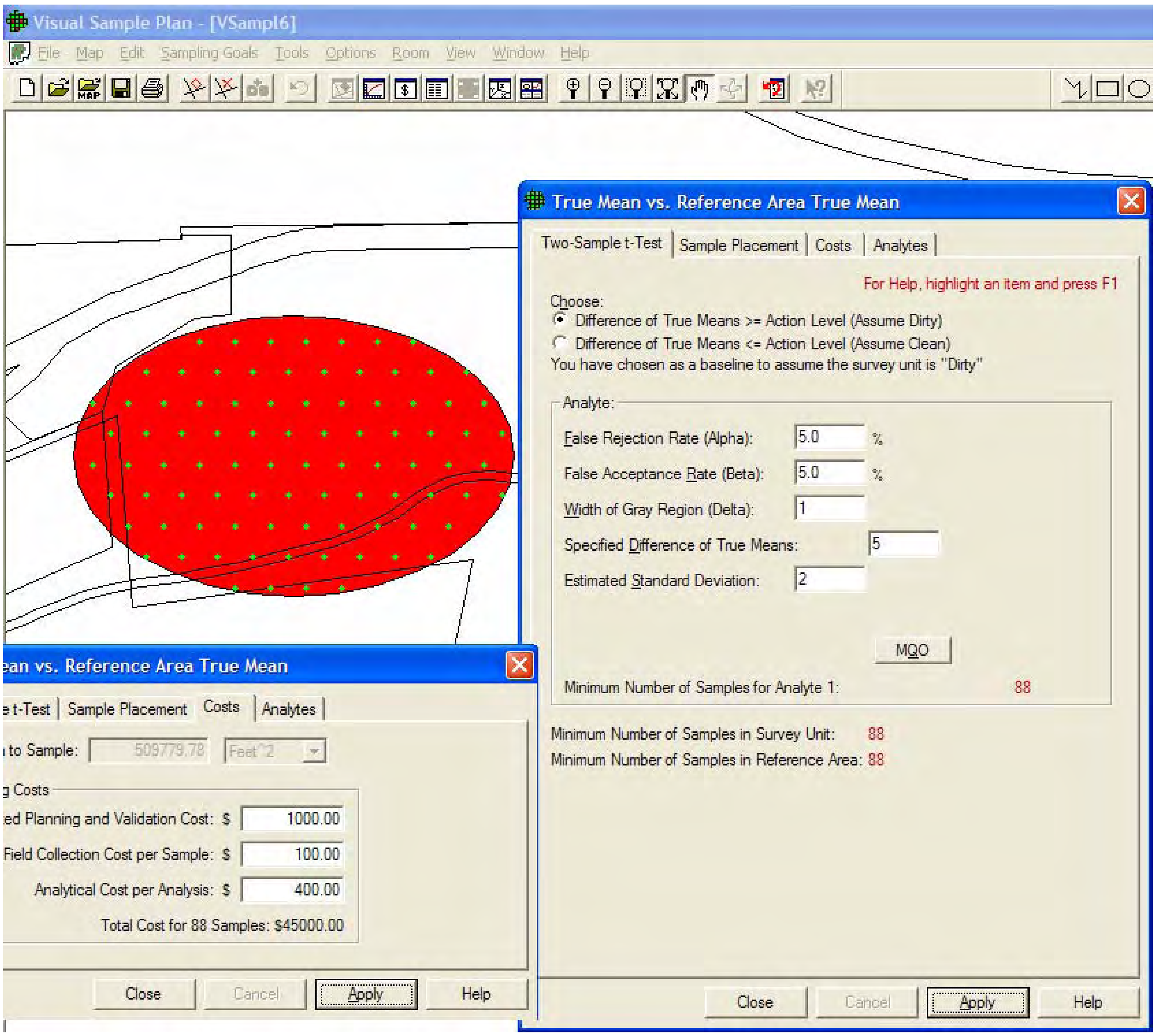


Figure 3.11a. Input Boxes for Case 4 with Increased Error Rates

Can we justify these larger error rates? Again, only professional judgment using the best information related to the current problem can answer that question.

What about our planned use of a parametric test, the two-sample t-test? A sample size of 88 is large enough that we can probably safely assume the two-sample t-test will meet the assumption of normality for the differences of sample means. We should test this assumption after the data are collected.

What about the assumption of approximately equal standard deviations for the measurements in the Sample and Reference Areas? When we collect the data, we will need to check that assumption. See *Guidance for Data Quality Assessment Practical Methods for Data Analysis* (EPA 2000b, pp. 3-26) for the use of Satterthwaite's t-test when the standard deviations (or variances) of the two areas are not approximately equal.

VSP Solution 4b: Taking the previous example, we now assume that the number of reference samples is fixed at 50, and the standard deviation for the reference samples is expected to be a slightly lower **1.5** pCi/g for the contaminant of interest. We want to calculate how many field samples to take while still meeting our parameters. We start by choosing from the main menu: **Sampling Goals > Compare Average to Reference Average > Can assume data will be normally distributed > Unqual sample sizes**. This module accounts for differences in sample sizes for reference and field samples, and also accounts for differences in standard deviations. The input dialog is shown in Figure 3.12b after entering parameters and clicking **Calculate**. VSP has run simulations and estimated that 58 field samples will be needed in addition to the 50 reference samples samples to achieve the desired alpha and beta levels to run a two-sample t-test.

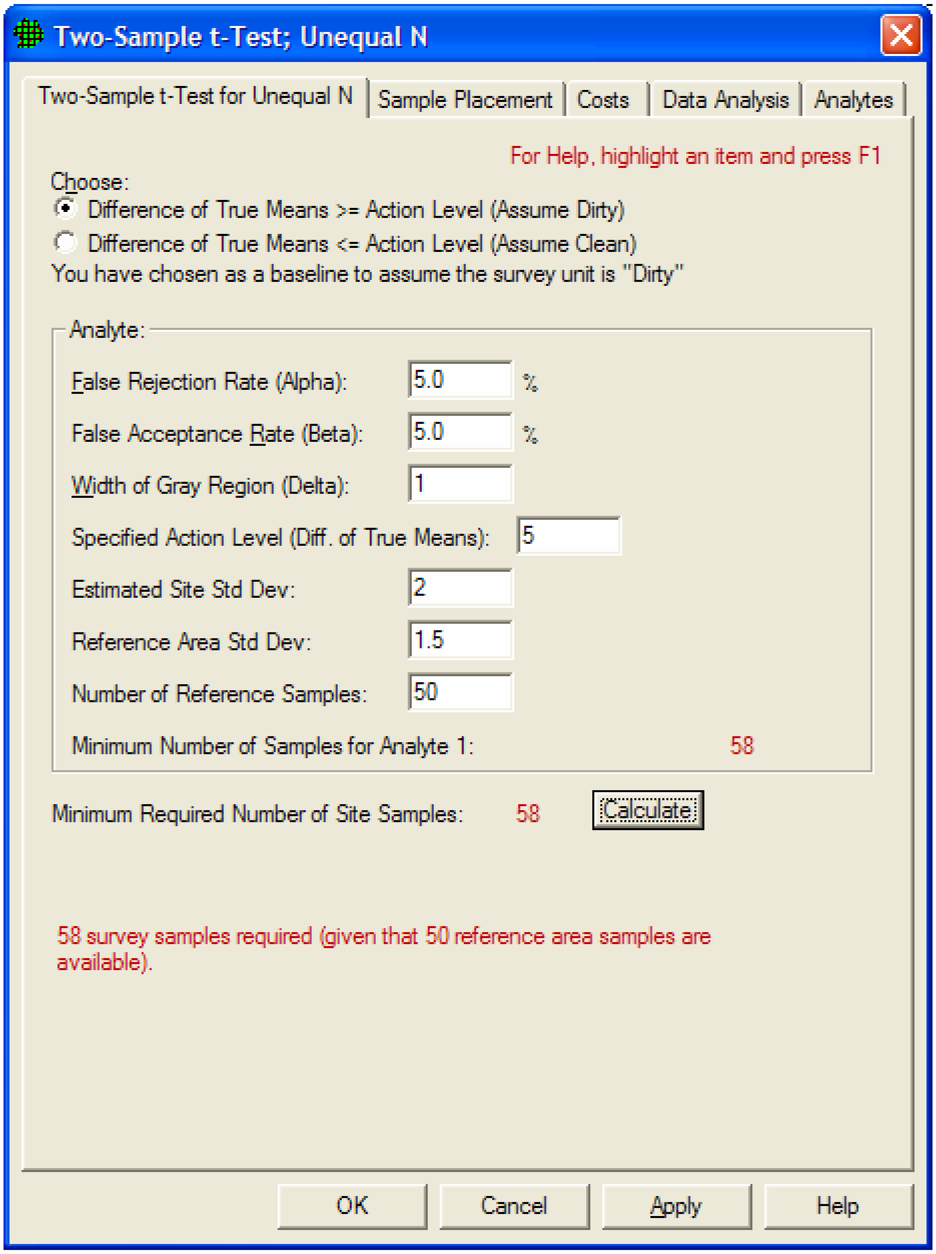


Figure 3.12b Input Dialog for Case 4 with Unequal Sample Sizes and Unequal Standard Deviations

Case 5: We now look at the case in which the nonparametric Wilcoxon Rank Sum (WRS) Test is planned for the data analysis phase of the project. VSP offers two versions of the WRS Test: the MARSSIM WRS test and the Wilcoxon Rank Sum Test. If the Sample and Reference population distributions are *not symmetric*, both WRS methods test the differences in the *medians*. If one wants to make a statement about the differences between *means* using the WRS tests, it is required that the two distributions be *symmetric* so that the mean equals the median. The verification testing done on VSP shows that the Wilcoxon rank sum test requires slightly higher sample sizes than the MARSSIM WRS test for the same set of inputs, assuming all the appropriate assumptions for each test are met.

The Wilcoxon rank sum test is discussed in *Guidance for Data Quality Assessment* (EPA 2000b, pp. 3-31 – 3-34). The document can be downloaded from the EPA at: **http://www.epa.gov/quality/qa_docs.html**. It tests a shift in the distributions of two populations. The two distributions are assumed to have the same shape and dispersion, so that one distribution differs by some fixed amount from the other distribution. The user can structure the null and alternative hypothesis to reflect the amount of shift of concern and the direction of the shift.

VSP Solution 5: We start by choosing from VSP's main menu **Sampling Goals > Compare Average to Reference Average > Data not required to be normally distributed > Ordinary sampling – no distributional assumption**. A grouping of the input dialogs is shown in Figure 3.13.

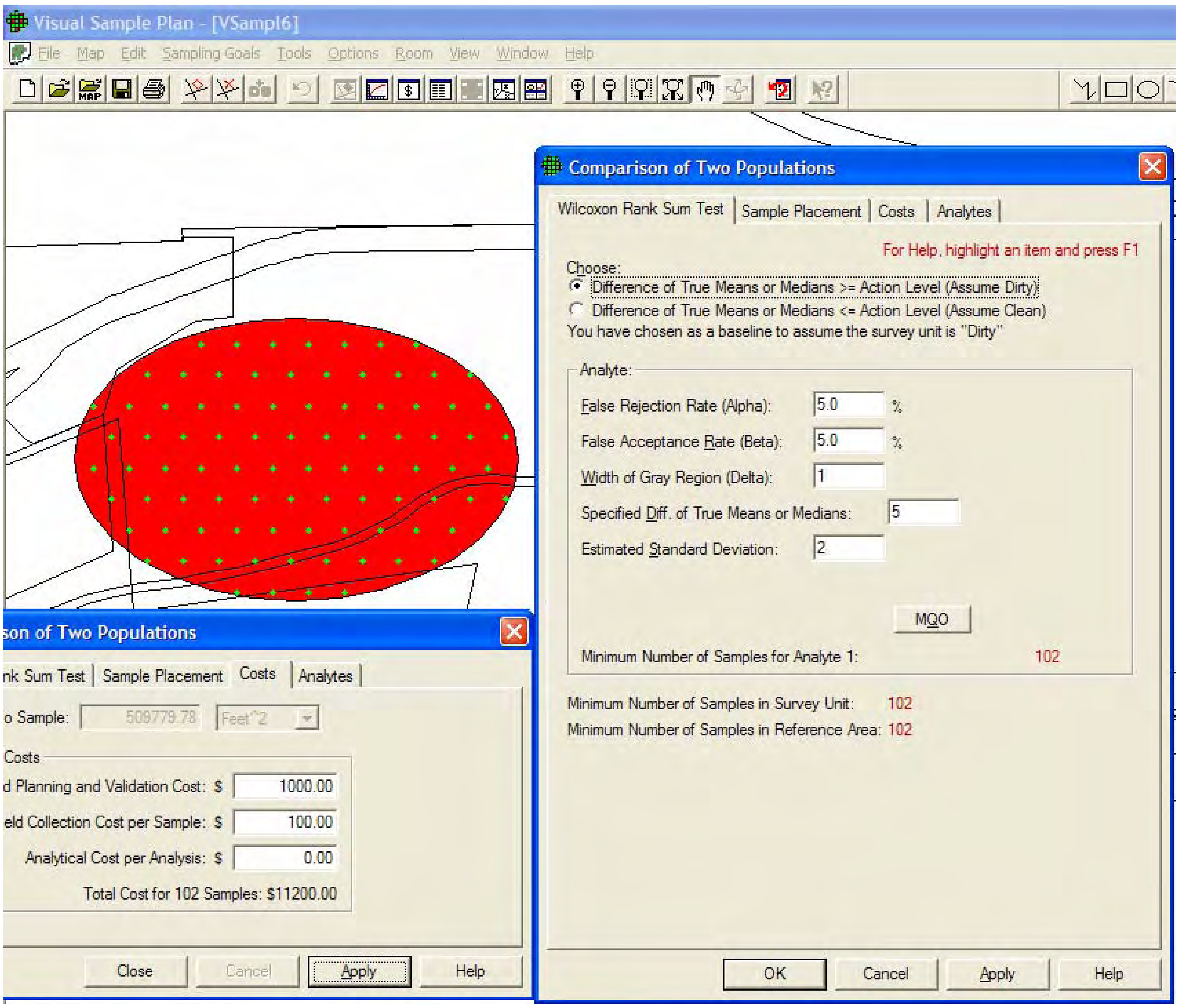


Figure 3.12. Input Boxes for Case 5 Using Nonparametric Wilcoxon Rank Sum Test

In Figure 3.13, you can see that the sample size increases to **102** for each sampling area, and the cost per area is now **$11,200**. The larger sample size of 102 instead of the previous sample size of 88 is probably not justified. However, professional judgment is needed to make the final decision.

Case 6: Next, assume that the population from which we will be sampling is non-normal but symmetric and we again desire to use a nonparametric Wilcoxon rank sum test. However, we are limited to a total sampling budget for *both* areas of $10,000. By using VSP iteratively, we will adjust the various DQO input parameters and try to discover a sampling plan that will meet the new goals.

VSP Solution 6: Figure 3.14 shows that with an alpha of **5%,** a beta of **20%,** and a lower bound of the gray region of **3.75**, the number of samples per area drops to **38**. With a sampling cost of **$4,800** for each sampling area, we now have a combined cost of **$9,600** and thus meet our goal of $10,000.

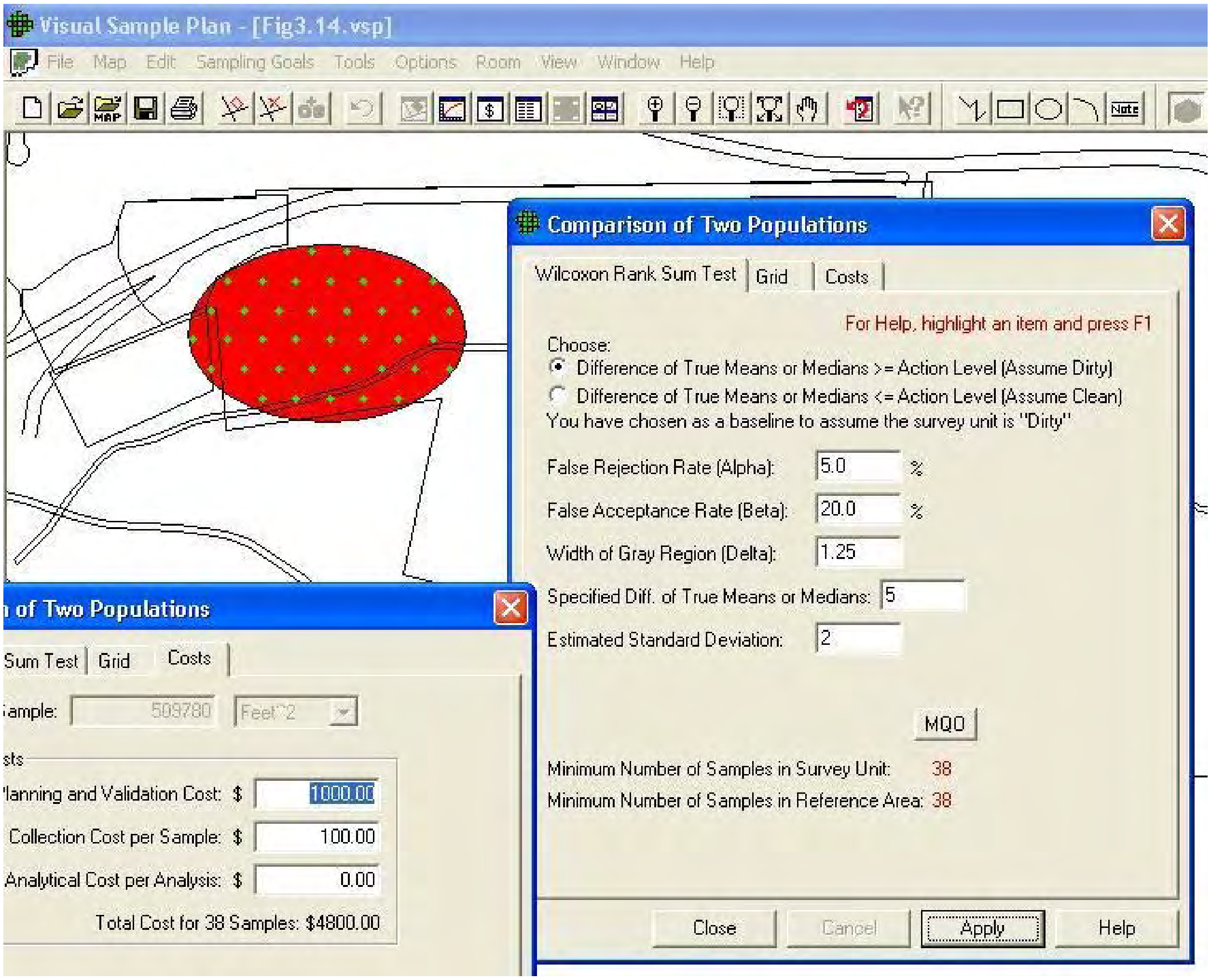


Figure 3.13. Input Boxes for Case 6 Using Nonparametric Wilcoxon Rank Sum Test

Will relaxing the error tolerances and increasing the width of the gray region to meet the requirements of the smaller sampling budget be acceptable to all stakeholders in the DQO process? Again, it depends on the objectives and judgment of those involved in the process.

Case 7: Suppose our combined sampling budget is reduced to $5,000. Can VSP provide a sampling design that meets that goal?

VSP Solution 7: Figure 3.15 shows a design with just **14** samples per sampling area that meets the new sparse budget. We reduced the combined sampling cost, now **$4,800**, by increasing the width of the gray region to **2.1** pCi/g (lower bound of the gray region is 2.9 pCi/g).

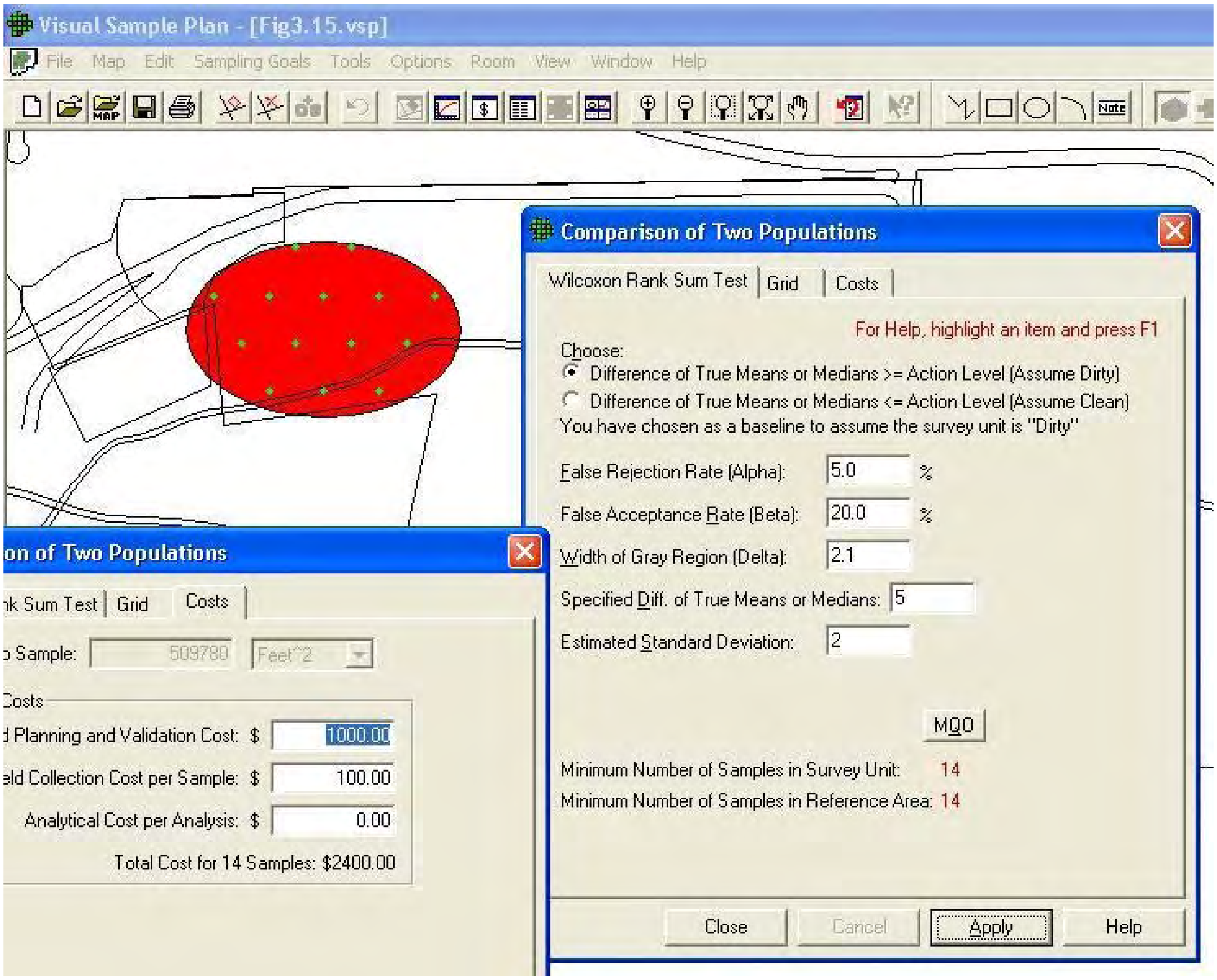


Figure 3.14. Input Boxes for Case 7 Using Nonparametric Wilcoxon Rank Sum Test

There are definite consequences of reducing sampling requirements to fit a budget. The consequences could include a greater chance of concluding that a dirty site is clean or a clean site is dirty. There is also a larger area of the gray region where you say you will not control (i.e., limit) the false acceptance error rate.

Is it justifiable to keep reducing the sampling budget in the above manner? Again, the answer depends on the specific problem. VSP, like most software, suffers from GIGO - Garbage In, Garbage Out. However, a responsible DQO process can provide valid information to VSP that overcomes GIGO and lets VSP help solve the current problem in an efficient manner.

Case 8: Now we assume we have seriously underestimated the standard deviation. Suppose that instead of 2 pCi/g, it is really 4 pCi/g. Now how many samples should we be taking?

VSP Solution 8: Figure 3.16a shows the new sample size has jumped to 53, almost a four-fold increase over the 14 samples used in VSP Solution 7. For many sample-size equations, the number of required samples is proportional to the square of the standard deviation, i.e., the variance. Thus, an underestimate of the standard deviation can lead to a serious underestimate of the required sample size.

If we seriously underestimate the standard deviation of the measurements, what will be the practical implications of taking too few samples? Remember that we have as a null hypothesis "Site is Dirty." If the site is really clean, taking too few measurements means we may have little chance of rejecting the null hypothesis of a dirty site. This is because we simply do not collect enough evidence to "make the case," statistically speaking.

Case 9: The MARSSIM WRS (Wilcoxon Rank Sum) test is a two-sample test that compares the distribution of a set of measurements in a Survey Unit (i.e., Sample Area) to that of a set of measurements in a Reference Area (i.e., background area). From the main menu, select **Sampling Goals > Compare Average to Reference Average > Data not required to be normally distributed > Ordinary sampling – no distributional assumption (MARSSIM).** The MARSSIM WRS test is used when the contaminant of

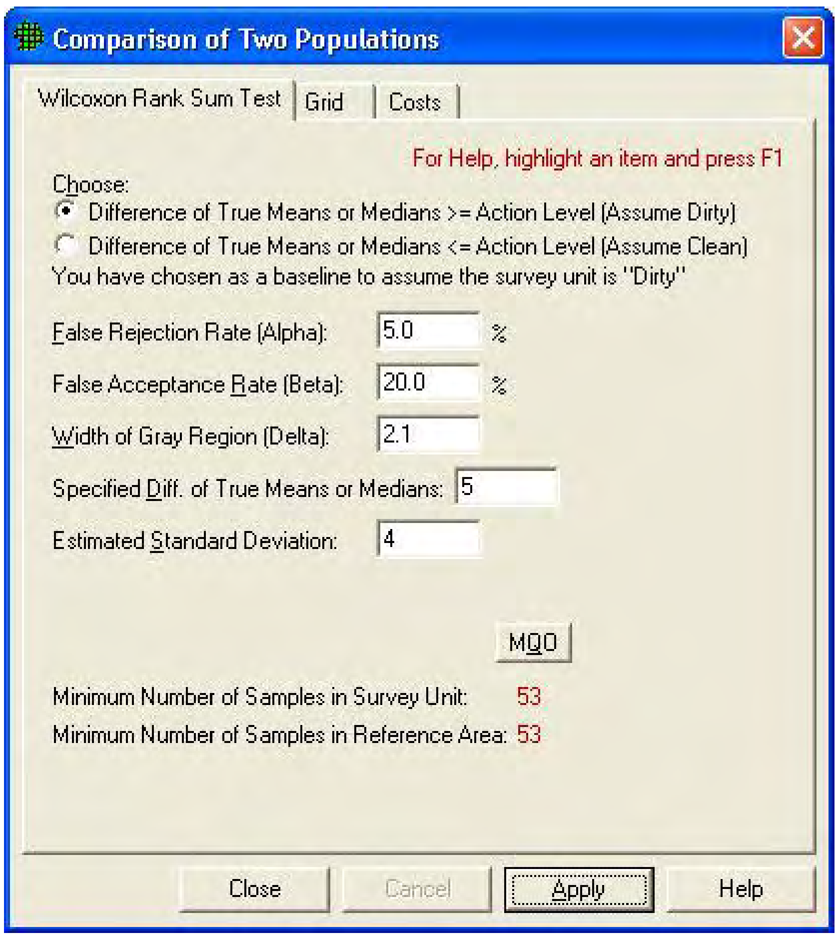


Figure 3.15a. Input Boxes for Case 8 with Larger Standard Deviation

concern in the Survey Unit is also present in the Reference Area, and the contamination is uniformly present throughout the Survey Unit. The MARSSIM WRS test is used to test whether the true median in a Survey Unit population is greater than the true median in a Reference Area population. The test compares medians of the two populations because the WRS is based on ranks rather than the measurements themselves. Note that if both the Survey Unit and Reference Area populations are symmetric, then the median and mean of each distribution are identical. In that special case the MARSSIM WRS test is comparing means. The assumption of symmetry and the appropriate use of the WRS test for final status surveys is discussed in Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (EPA 2000). This document is currently available at: **http://www.epa.gov/radiation/marssim/**.

Shown in Figure 3.16b, the input dialog for the MARSSIM WRS test allows the user to supply a percent overage to apply to the sample size calculation. MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and for uncertainty in the calculated values of Sample Size, (MARSSIM, p. 5-29). With the extra 20%, the sample size now becomes **53** samples required in both the Sample Area (i.e., Survey Unit or Study Area) and Reference Area.

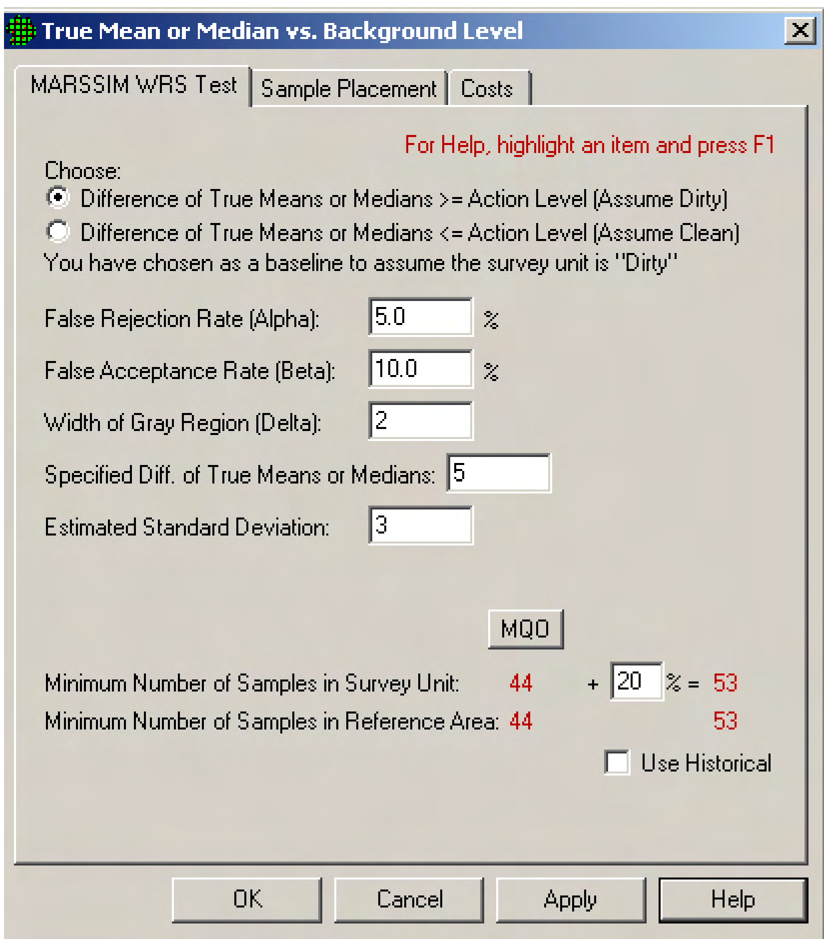


Figure 3.16b. Input Box for Case 9 Using the MARSSIM WRS Test

3.2.3 Estimate the Mean

When the Sampling Goal is to **Estimate the Mean > Data not required to be normally distributed,** three design options are offered in VSP. None of the three requires the assumption of normality as the underlying distribution of units in the population. The options are:

- stratified sampling
- ranked set sampling
- collaborative sampling

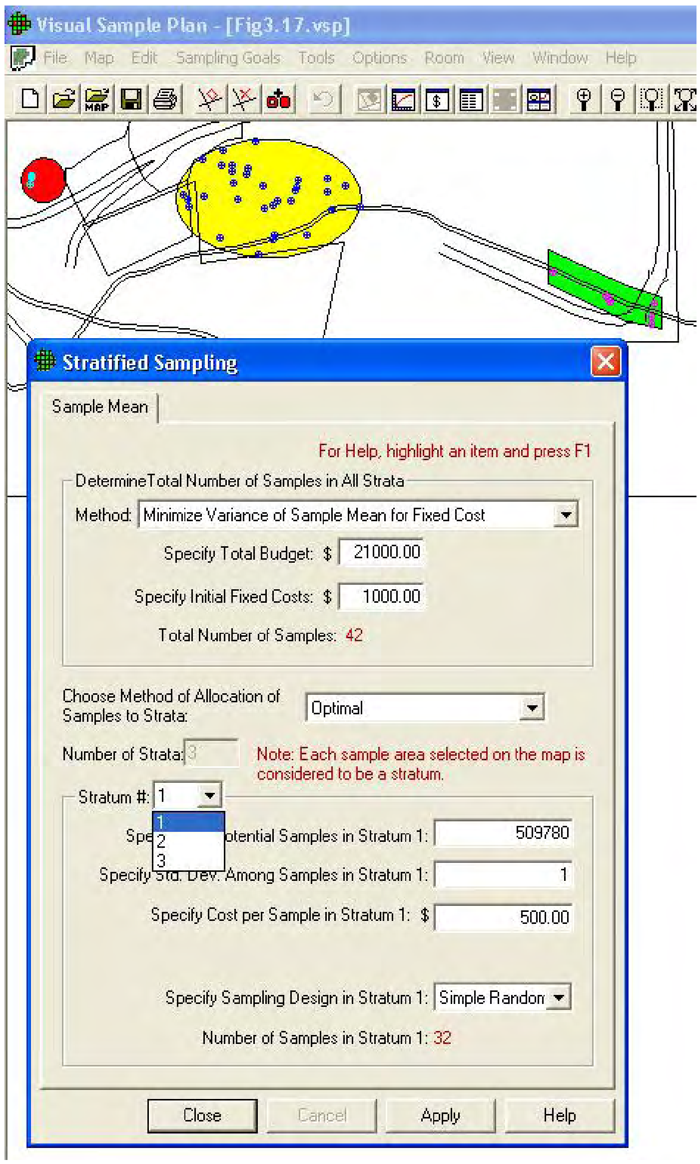


Figure 3.16. Dialog Box for Stratified Sampling for Estimating a Mean

3.2.3.1 Stratified Sampling

In Figure 3.17, we see the dialog box for entering parameters for stratified sampling. Prior to running VSP to calculate sample sizes for the strata, the user must have pre-existing information to divide the site into non-overlapping strata that are expected to be more homogeneous internally than for the entire site (i.e., all strata). They must be homogeneous in the variable of interest for which we want to calculate a mean. The strata are the individual user-selected Sample Areas and can be seen using Map View.

With the Sample Areas selected (VSP shows total number of areas in **Numbers of Strata),** the dialog shows the initial values VSP assigns to the various inputs. The number of potential samples in each stratum is initially set at the number of 1-square-foot (or whatever units are used) units available to be sampled or approximately the **area of the Sample Area** (shown when the area is first selected). If the sample support is not a 1-square-foot volume, the user should change this to the correct value. The initial standard deviation between individual units in the stratum is assigned the value **1.** It is in the same units as the mean. This is a critical value in the sample size calculation, so the user should make sure this is a good estimate. The sampling and measurement costs per sample in each stratum and the fixed costs are input in dollars. After entering the values for stratum 1, the user selects the next stratum from the drop-down list under **Stratum #.**

VSP allows simple random sampling or systematic within the strata. This is selected using the pull-down menu under **Specify Sampling Design in Stratum n.**

The other inputs required by VSP pertain to the method the user wants to use for determining 1) the total number or samples in all strata and 2) the allocation of samples to strata. Methods are selected from the drop-down lists. VSP Help offers some insight into why one method might be selected over another, but the user should use the DQO process to flush out the site-specific conditions and project goals that will determine these inputs. Different inputs are required depending on which method is selected for determining the total number of samples. After you press **Apply,** the dialog shows in red the total number of samples and the number of samples in each stratum (use the pull-down **Stratum #** to switch between strata). You can see the placement of samples within strata by going to **Map View.**

3.2.3.2 Ranked Set Sampling

Ranked set sampling (RSS) is the second option for the Sampling Goal: **Estimate the Mean > Data not required to be normally distributed.** The number of inputs required for RSS is the most of any of the designs available in VSP. However, RSS may offer significant cost savings, making the effort to evaluate the design worthwhile. The VSP Help, the VSP technical report (Gilbert et al. 2002), and EPA (2001, pp. 79–111) are good resources for understanding what is required and how VSP uses the input to create a sampling design.

A simple example given here will explain the various input options. The user should have gone through the DQO process prior to encountering this screen because it provides a basis for inputs.

Under the tab **Ranked Set Sampling,** the first set of inputs deals with whether this design has any cost advantages over simple random sampling or systematic sampling where every unit that is sampled is measured and analyzed.

We select **Symmetric** for the distribution of lab data, thus telling VSP we think the lab data is distributed normally so VSP should use a balanced design. A balanced design has the same number of field locations, say $r = 4$, sampled for each of the say $m = 3$ ranks. That is, a sample is collected at each of the four locations expected to have a relatively small value of the variable of interest, as well as at the four locations expected to have a mid-range value, and at four locations expected to have a relatively large value. An unbalanced design has more samples collected at locations expected to have large values. EPA says that a balanced design should be used if the underlying distribution of the population is symmetric (EPA 2001, p. 86).

We select **Professional Judgment** as the ranking method. This selection requires us to say whether we think there is Minimal or Substantial error in our ranking ability. We select **Minimal.** Note: if we had chosen to use some type of Field Screening device to do the ranking, we would need to provide an estimate of the correlation between the field screening measurements and accurate analytical lab measurements. We choose a set size of **3** from the pull-down menu. The set size we select is based on practical constraints on either our judgment or the field screening equipment available.

Note: VSP uses set size to calculate the factor by which the cost of ranking field locations must be less than lab measurement costs in order to make RSS cost-effective. For our example, VSP tells us this factor must be at least **3** times.

The next set of inputs required for RSS is information required to calculate the number of samples needed for simple random sampling. This value, along with cost information, is used to calculate the number of cycles, *r*. We say we want a **one-sided confidence interval** (we want a tight upper bound on the mean and are not concerned about both over- and underestimates of the sample mean), we want that interval to contain **95%** of the possible estimates we might make of the sample mean, we want that interval width to be no greater than **1** (in units of how the sample mean is measured), and we estimate the standard deviation between individual units in the population to be **3** (in units of how the sample mean is measured). VSP tells us that if we have these specifications, we would need **26** samples if we were to take them randomly and measure each one in an analytical lab.

The box in the lower right corner of this dialog gives us VSP's recommendations for our RSS design: we need to rank a total of **45** locations. However, we need to send only **15** of those off to a lab for accurate measurement. This is quite a savings over the **26** required for simple random sampling. There will be *r* = **5** cycles required.

Note: If we had chosen an unbalanced design, VSP would tell us how many times the top ranked location needed to be sampled per cycle. Also, the inputs for the confidence interval would change slightly for the unbalanced design.

All costs (fixed, field collection per sample, analytical cost for sending a sample to the lab, and ranking cost per location) are entered on the dialog box that appears when the **Cost** tab is selected. In Figure 3.18, we see the two dialog boxes for RSS.

Once we press **Apply,** the RSS toolbar appears on our screen. The RSS toolbar lets us explore the locations to be ranked and the locations to be sampled and measured under **Map View.** VSP produces sample markers on the map that have different shapes and colors. The color of the marker indicates its cycle. The cycle colors start at red and go through the spectrum to violet. Selecting one of the cycles on the pull-down menu displays only the field locations for that cycle. In Figure 3.19, all the green field locations for **Cycle 3** are shown. The shape of the marker indicates its set. Field sample locations for the first set are

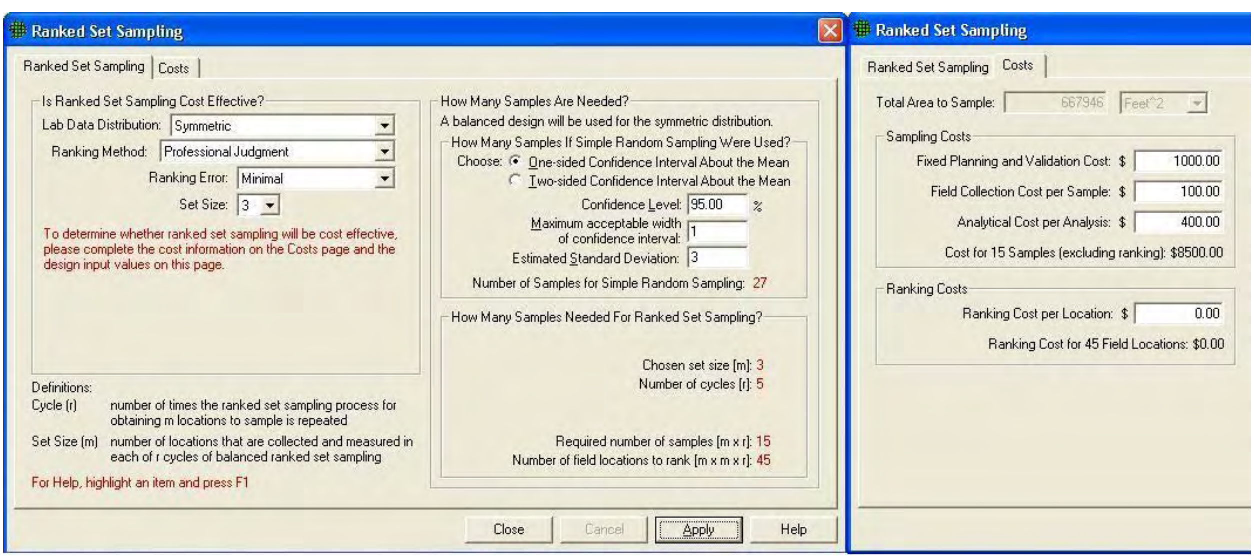


Figure 3.17. Dialog Boxes for Ranked Set Sampling Design

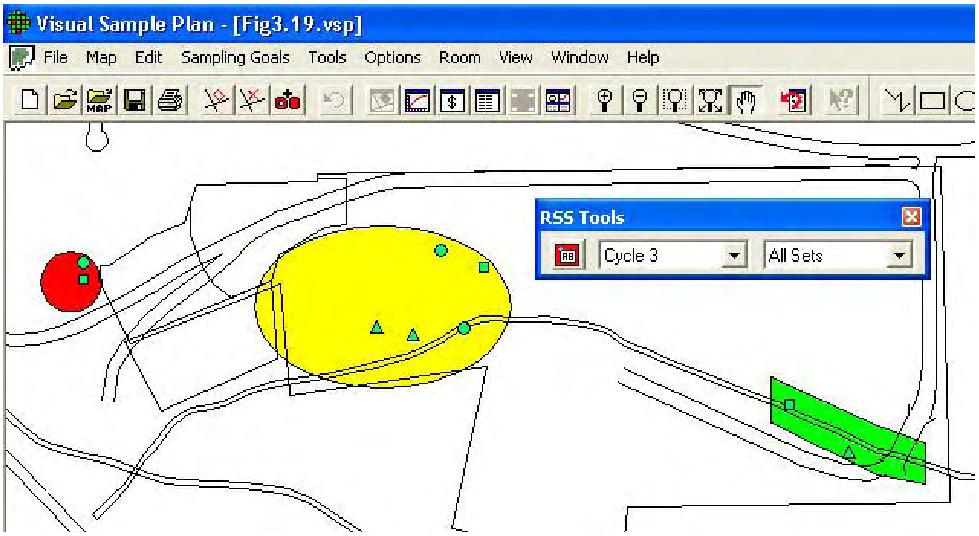


Figure 3.18. Map of RSS Field Sample Locations for All Sets in Cycle 3, Along with RSS Toolbar

marked with squares, locations for the second set are marked with triangles, and so on. We show **All Sets** in Figure 3.19. For unbalanced designs, the top set is sampled several times, so a number accompanies those markers. Our example is for a balanced design so we do not see numbers.

Ranked set field sampling locations are generated with a label having the following format: RSS-c-s-i

where c = the cycle number
s = the set number (the unbalanced design for this number is also incremented for each iteration of the top set)
I = a unique identifier within the set.

Use **View** > **Labels** > **Labels** on the main menu or the **AB** button on the main toolbar (button also on the RSS toolbar) to show or hide the labels for the field sample locations. Figure 3.20 shows the labels on the map for field sample locations associated with **Cycle 3, All Sets.**

3.2.3.3 Collaborative Sampling for Estimating the Mean

The third design we discuss for a cost-effective option for estimating the mean when normality cannot be assumed is Collaborative Sampling (CS) – sometimes called Double Sampling. This design is applicable where two or more techniques are available for measuring the amount of pollutant in an environmental sample, for

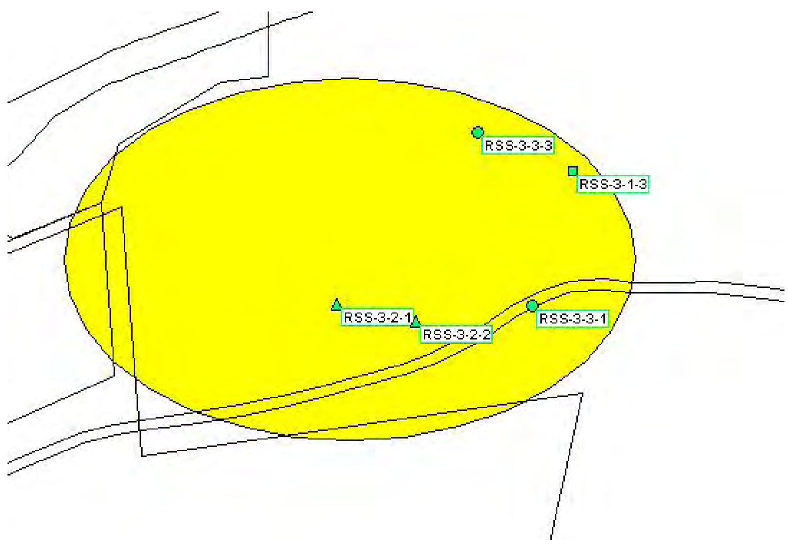


Figure 3.19. Map of RSS Field Sampling Locations Along with Their Labels

example a field method (inexpensive, less accurate) and a fixed lab method (expensive, more accurate). The approach is to use both techniques on a small number of samples, and supplement this information with a larger of number of samples measured only by the more expensive method. This approach will be cost-effective if the linear correlation between measurements obtained by both techniques on the same samples is sufficiently near 1 and if the less accurate method is substantially less costly than the more accurate method

Collaborative Sampling works like this: At *n* field locations selected using simple random sampling or grid sampling, the inexpensive analysis method is used. Then, for each of n_E of the *n* locations, the expensive analysis method is also conducted. The data from these two analysis methods are used to estimate the mean and the standard error (SE: the standard deviation of the estimated mean). The method of estimating the mean and SE assumes there is a linear relationship between the inexpensive and expensive analysis methods.

VSP has an extensive discussion of CS in the **Help**. CS is also discussed in Gilbert (1987), Chapter 9, where you can find an actual Case Study using CS. In Figure 3.21 we show the input screen for Collaborative Sampling.

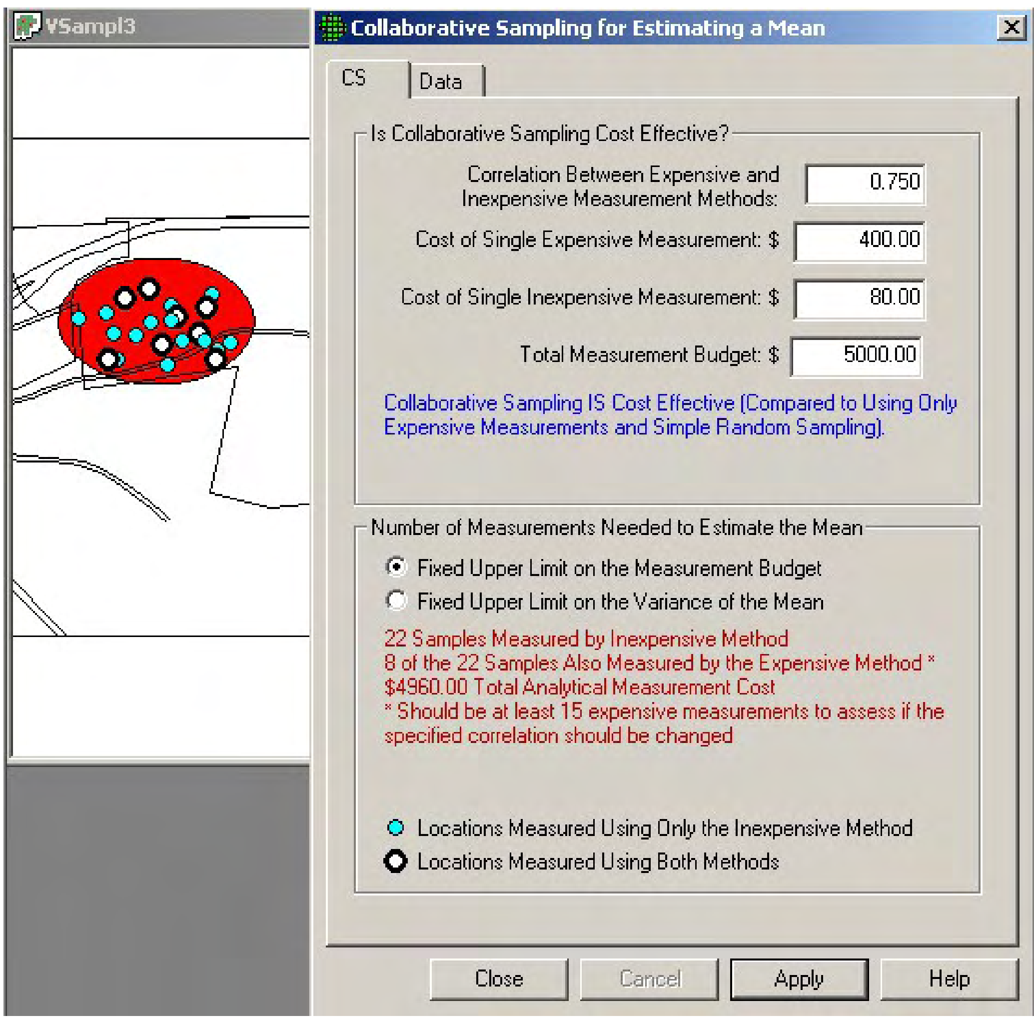


Figure 3.20. Input Dialog Box for Collaborative Sampling for Estimating the Mean

For this example, we applied CS samples to an area on the Millsite map. After inputting the costs of each measurement technique, the total budget, and an estimate of the correlation between the two methods, VSP informs you whether or not CS is cost effective. For the vales we input, we see that it is cost effective. Then VSP uses the formulas discussed in the On-Line Help and the Report view to calculate two sample sizes, n (22), and n_E (8). There are two options for optimizing the values of n and n_E that the VSP user must select from:

- estimate the mean with the lowest possible standard error (SE: the standard deviation of the estimated mean) under the restriction that there is a limit on the total budget, or

- estimate the mean under the restriction that the variance of the estimated mean (square of the SE) does not exceed the variance of the mean that would be achieved if the entire budget were devoted to doing only expensive analyses.

We select the first option. VSP calculates that we need to take 22 samples and measure them with the inexpensive method, 8 of which are also measured using the more expensive methods. However, we get a warning message that we should be taking at least 15 measurements where we use both methods in order for VSP to assess whether our initial estimate of a 0.75 linear correlation coefficient is correct. Note that after we hit the **Apply** button, we see the sampling locations placed on the Sample Area we selected (Millsite.dxf used for this example).

As with Collaborative Sampling for Hypothesis Testing discussed in Section 3.2.1, VSP requires us to input the results of the sampling to verify that the computed correlation coefficient is close to the estimated correlation coefficient used to calculate the sample sizes. Data Results are input in the dialog box that appears after selecting the **Data** tab (see Figure 3.10a). VSP calculates the estimated mean and standard deviation of the estimated mean once the data values are input.

3.2.3.4 Adaptive Cluster Sampling

Adaptive cluster sampling is appropriate if we can assume the target population is normally distributed: **Sampling Goal > Estimate the Mean > Can assume data will be normally distributed > Adaptive Cluster Sampling.** Because adaptive designs change as the results of previous sampling become available, adaptive cluster sampling is one of the two VSP designs that require the user to enter sample values while planning a sampling plan. (The other design that requires entering results of previous sampling is sequential sampling; see Section 3.2.1). The VSP Help, the VSP technical report (Gilbert et al. 2002), and the EPA (2001, pp. 105-112) are good resources for understanding what is required and how VSP uses the input to create a sampling design. A simple example here will explain the various input options. The user should have gone through the DQO process prior to encountering this screen because it provides a basis for inputs.

The screen for entering values in the dialog box is displayed by selecting the tab **Number of Initial Samples.** Adaptive cluster sampling begins by using a probability-based design such as simple random sampling to select an initial set of field units (locations) to sample. To determine this initial sample number, either a one-sided or two-sided confidence interval is selected. We select **One-sided Confidence Interval** and enter that we want a **95%** confidence that the true value of the mean is within this interval. We want an interval width of at least **1** and we estimate the standard deviation between individual units in the population to be **2** (units of measure for interval width and standard deviation is same as that of individual sample values). VSP returns a value of **13** as the minimum number of initial samples we must take in the Sample Area.

In Figure 3.22, we can see the 13 initial samples as yellow squares on the map.

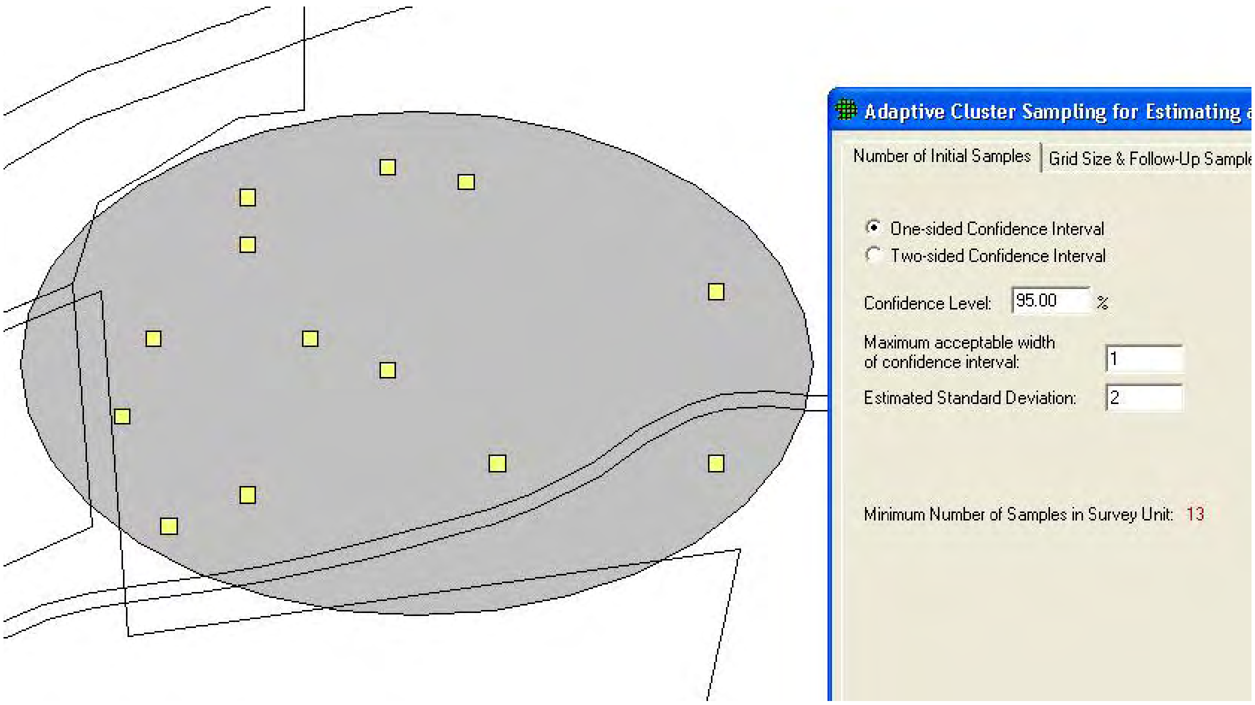


Figure 3.21. Map of Sample Area with Initial Samples for Adaptive Cluster Sampling Shown as Yellow Squares, Along with Dialog Box

The user now enters the analytical measurement results for the initial 13 sampling units. (Adaptive cluster sampling is most useful when quick turnaround of analytical results is possible, e.g., use of field measurement technology.) Place the mouse directly over each sample and right-click. An input box appears as shown in Figure 3.23. Enter a **measurement** value (shown here as **8)** and, if desired, a **label** (shown here as **AC1-25-62).** Press **OK.** Enter another sample value and continue until all 13 sample values have been entered.

Select tab **Grid Size & Follow-Up Samples** on the Adaptive Cluster for Estimating a Mean dialog box. Enter the desired Grid Size for Samples, shown here as **20 ft,** and an upper threshold measurement value that, if exceeded, triggers additional sampling. We chose **10** as the threshold. We have a choice of how to expand sampling once the threshold is exceeded: 4 nearest neighbors or 8 nearest neighbors. We choose **4.** The dialog box is shown as the insert in Figure 3.24a. The grid units can be orientated at different angles by **selecting Edit > Sample Areas > Set Grid Angle** and **Edit > Sample Areas > Reset Grid Angle** from the main menu.

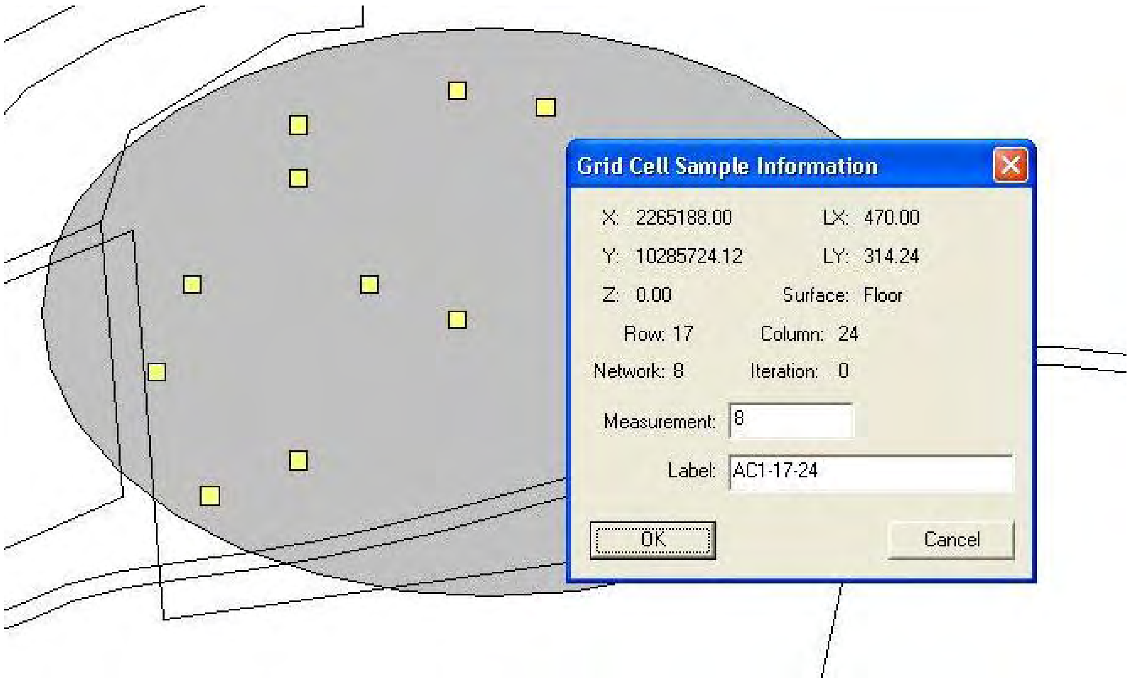


Figure 3.22. Dialog Input Box for Entering Sample Measurement Values and Labels for Initial Samples in Adaptive Cluster Sampling

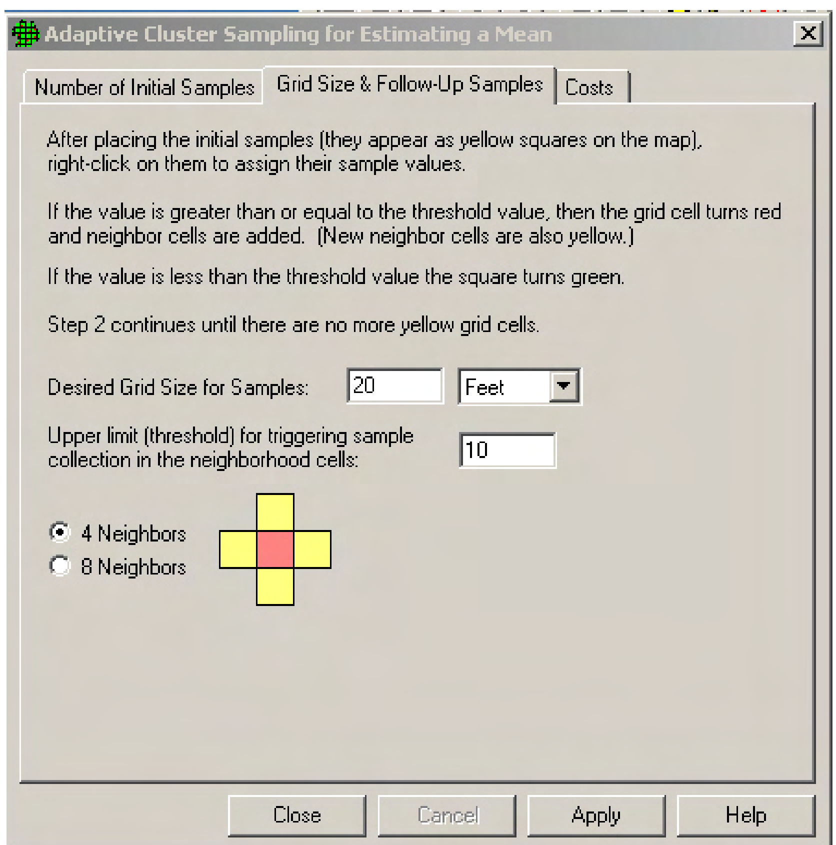


Figure 3.23a. Dialog Input Box for Entering Grid Size and Follow-up Samples

Once **Measurement** values have been entered, the yellow squares turn to either green, indicating the sample did not exceed the threshold, or red, indicating the sample exceeded the threshold. The red samples are surrounded with additional yellow squares that now must be sampled. This process continues until there are no more yellow grid cells. In Figure 3.24b, we see examples of green, single yellow, red surrounded by yellow, and red surrounded by green. Sampling and measurement continues until all the initial samples are green or red and all the added samples are green or red.

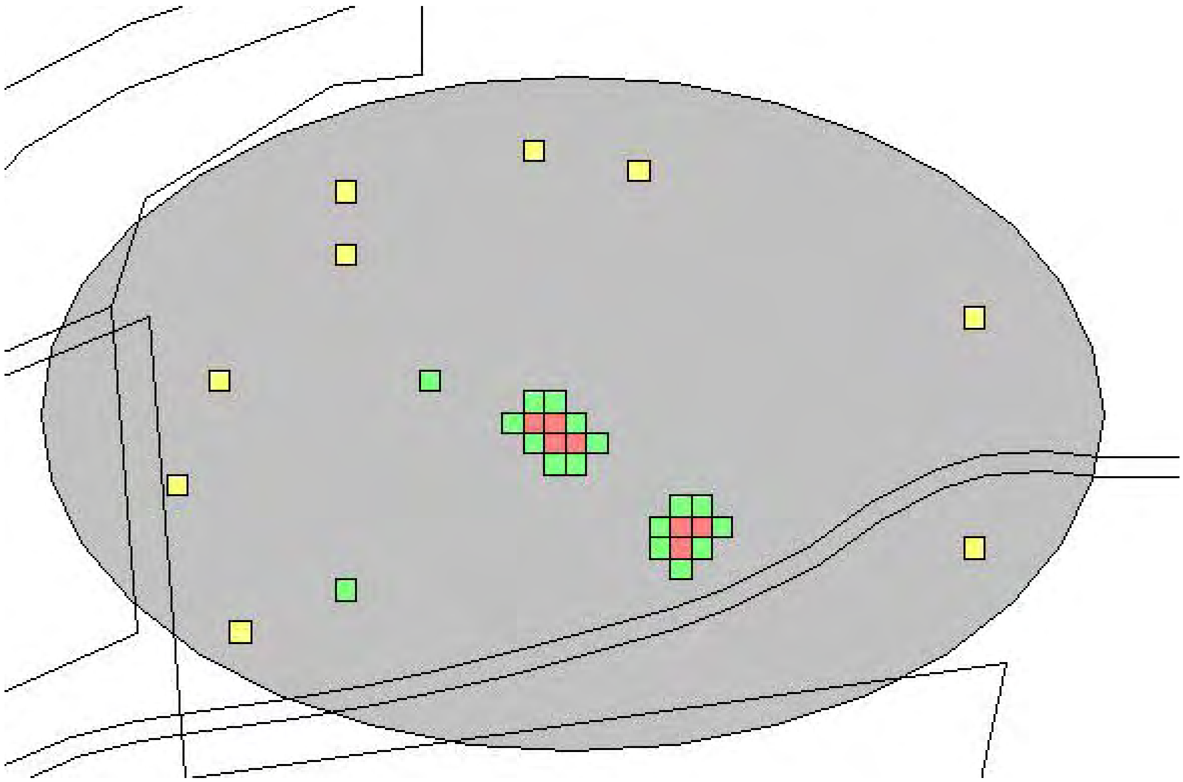


Figure 3.24b. Examples of Combinations of Initial and Follow-up Samples from Adaptive Cluster Sampling

Costs are entered using the **Cost** tab on the dialog box. The **Report** for adaptive cluster sampling shows the total cost for all the initial samples plus follow-up samples and provides an (unbiased) estimate of the mean and its standard error. Refer to VSP's **Help** for a complete discussion of adaptive cluster sampling.

3.2.4 Construct Confidence Interval on Mean

If the VSP wants a confidence interval on the true value of the mean, not just a point estimate of the mean as calculated in Section 3.2.3, the user selects **Sampling Goal > Construct Confidence Interval on the Mean**. Currently VSP has algorithms for only the case where the data can assumed to be normally distributed. Within that category, the user can choose **Ordinary Sampling** or **Collaborative Sampling**.

For **Ordinary Sampling**, four DQO inputs are required:

- whether a one- or two-sided interval is desired,
- the confidence you want to have that the interval does indeed contain the true value of the mean,

- the maximum acceptable half-width of confidence interval, and
- an estimate of the standard deviation between individual units of the population.

The two-sided confidence interval, smaller interval width sizes, and larger variation generally require more samples. In Figure 3.25, we see an example of the design dialog for the Confidence Interval on the Mean sampling goal for Ordinary Sampling, along with the recommended sample size of **38** that VSP calculated.

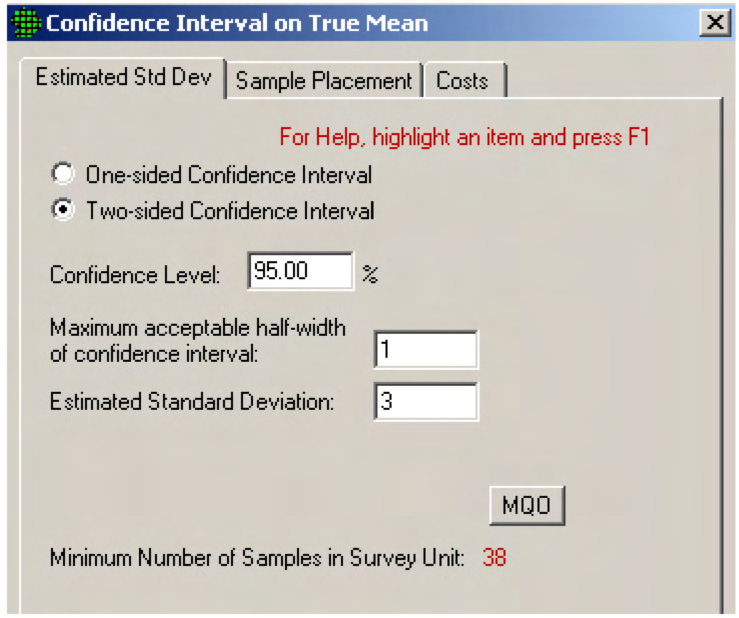


Figure 3.24. Dialog Input Box for Calculating a Confidence Interval on the Mean using Ordinary Sampling

If the user has more than one type of sample measurement method available, **Collaborative Sampling** should be explored to see if cost savings are available. Though not shown here, the inputs for Collaborative Sampling for Confidence Interval are similar to those in Figure 3.25, with the added cost inputs required to determine if Collaborative Sampling is cost effective (see discussion of Collaborative Sampling in Section 3.2.3.3). Note that under the sampling goal of Construct Confidence Interval on the Mean, Collaborative Sampling is put under the assumption of "normality", while for the sampling goal of Estimate the Mean, Collaborative Sampling is put under the assumption of "Data not required to be normally distributed." This is because for Estimating the Mean, the calculation of sample size *n* is based on restrictions on the budget or restrictions on the variance which make no distributional assumptions; while for Construct Confidence Interval on the Mean, the calculation of *n* is based on percentiles of the standard normal distribution.

3.2.5 Compare Proportion to Fixed Threshold

For comparing a proportion to a threshold (i.e., a given proportion), the designs available in VSP do not require the normality assumption. A one-sample proportion test is the basis for calculating sample size. The inputs required to calculate sample size are shown in the design dialog in Figure 3.26. The DQO inputs are similar to those for comparing an average to a fixed threshold, but since the variable of interest is a proportion (percentage of values that meet a certain criterion or fall into a certain class) rather a measurement, the action level is stated as a value from 0.01 to 0.99. Based on the inputs shown in Figure 3.26, VSP calculates that a sample size of 23 is required.

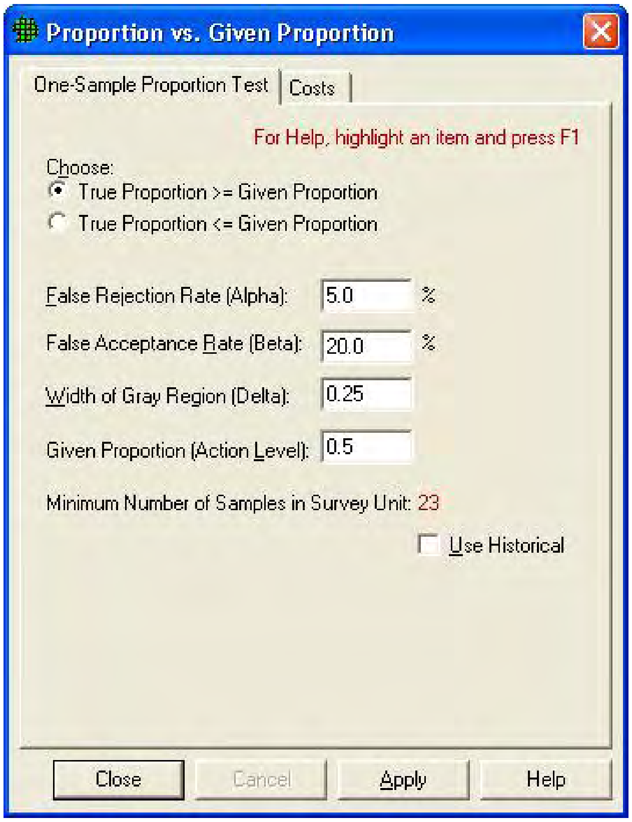


Figure 3.25. Design Dialog for Comparing a Proportion to a Fixed Threshold

Note that if the proportion of interest is the proportion of positive units in the environment, say the proportion of one-acre lots within a development area that have trees, then we need to select the null hypothesis that affords us the greatest protection against a false acceptance. In Figure 3.27, we see an example of the design dialog for this sampling goal. VSP calculates that we need 49 samples in the survey unit and 49 samples in the reference area for this set of inputs.

If no previous information is available on which to estimate the proportions in the survey unit or reference area, use 0.5 because at that value the sample sizes are the largest (i.e., the most conservative).

3.2.7 Estimate the Proportion

Similar to the designs available for estimating the mean, we see that VSP offers stratified sampling for the sampling goal of estimate the proportion because a

3.2.6 Compare Proportion to Reference Proportion

VSP formulates this problem as an environmental cleanup problem in which we have the proportion of contamination within a survey unit (Population 1) and we want to see if the difference between it and a reference area (Population 2) is greater (or less than) a specified difference. This specified difference becomes the action level. If we select the first formulation of the problem (P1 – P2 ≥ specified difference), we must enter a lower bound for the gray region. If we select the second formulation (P1 – P2 ≤ specified difference), we must enter an upper bound for the gray region. We must also enter our best guess of what we think the proportion of contamination is in both the survey unit and the reference unit. These two values are required to estimate the standard deviation of the proportions, which are then used as inputs to the sample size formula.

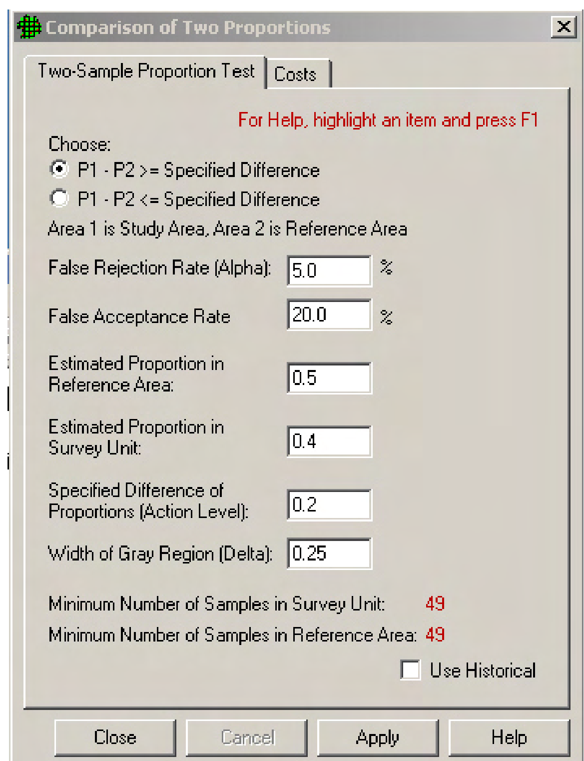


Figure 3.26. Design Dialog for Comparing a Proportion to a Reference Proportion

stratified design may be more efficient than either simple random sampling or systematic sampling. Designs and sample size formulas for a simple random selection of samples are not in the current release of VSP but can be found in standard statistics textbooks.

Prior to running VSP to calculate sample sizes for the strata, the user must have pre-existing information to use as the basis for dividing the site into non-overlapping strata. The strata should be more homogeneous internally than for the entire site (i.e., all strata). They must be homogeneous in the proportion of units that fall into one classification or another. The strata are the individual Sample Areas that the user selected and can be seen using **Map View.**

With the Sample Areas selected (VSP shows total number of areas in **Numbers of Strata),** the user may now open the dialog box. Note: Opening the dialog box prior to having Sample Areas selected will result in errors. Figure 3.28 shows the dialog box for one set of inputs.

The dialog box is separated into two blocks: the top deals with total number of samples in all strata; the bottom deals with allocation of total samples to individual strata. The user must select a method from the pull-down menu in each box. Different input is required depending on which method is selected. The **Help** function describes the various inputs required, why one method might be selected over another, and how they are used to calculate sample size. For methods where an estimate of the variance is required, the initial variance between individual units in the stratum is assigned the value **1.** It is in the same units as the mean. This is a critical value in the sample size calculation so the user should make sure this is a good estimate. In the bottom box, once values for stratum 1 are entered, the user selects the next stratum from the drop-down list under **Stratum #.**

VSP allows simple random sampling or systematic grid sampling within the strata. This is selected using the pull-down menu under **Specify Sampling Design in Stratum *n*.**

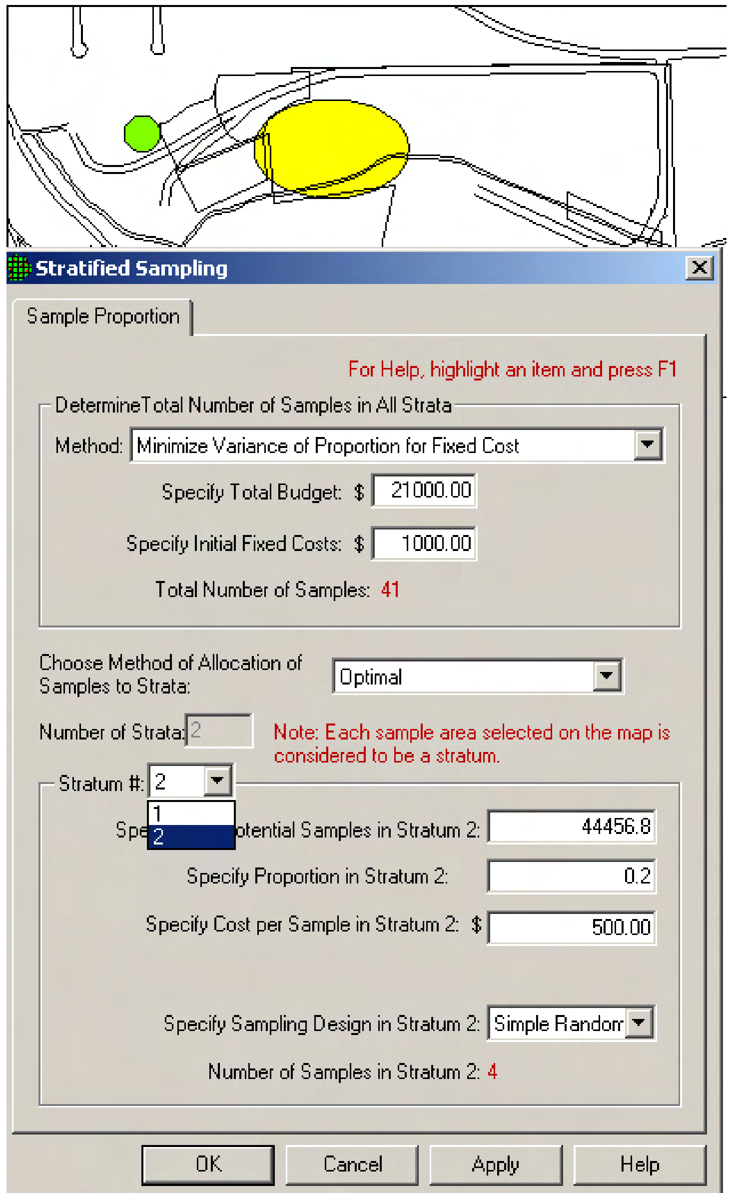


Figure 3.27. Dialog Box for Estimating a Proportion using Stratified Sampling

After supplying the required input, press **Apply** and the dialog shows in red the total number of samples and the number of samples required in each stratum (use the pull-down **Stratum #** to switch between strata). You can see the placement of samples within strata by going to **Map View.**

3.2.8 Locating a Hot Spot

There will be occasions when it is necessary to determine with a specified high probability that no hot spots of a specified size and shape exist in the study area. A hot spot is a local contiguous area that has concentrations that exceed a threshold value. Initially, the conceptual site model should be developed and used to hypothesize where hot spots are most likely to be present. If no hot spots are found by sampling at the most likely locations, then VSP can be used to set up a systematic square, rectangular or triangular sampling grid to search for hot spots. Samples or measurements are made at the nodes of the systematic grid. The VSP user specifies the size and shape of the hot spot of concern, the available funds for collecting and measuring samples, and the desired probability of finding a hot spot of critical size and shape. Either circular or elliptical hot spots can be specified.

The VSP user can direct VSP to compute one or more of the following outputs:

- The number and spacing of samples on the systematic sampling grid that are required to achieve a specified high probability that at least one of the samples will fall on a circular or elliptical hotspot of the specified size.

- The probability that at least one of the samples collected at the nodes of the specified systematic sampling grid will fall on a circular or elliptical hot spot of specified size.

- The probability that at least one of the samples will fall on a hot spot of the specified size given that the spacing between nodes of the systematic sampling grid is the minimum that can be achieved with project funding.

- The smallest size circular or elliptical hot spot that will be detected with specified high probability by sampling at the nodes of the systematic sampling grid.

The basic structure for these problems is that there are four variables (grid spacing, size of hot spot, probability of hitting a hot spot, and cost). You can fix any three of them and solve for the remaining variable.

The other unique feature of the hot spot problem is that there is only one type of error—the false negative or alpha error. VSP asks for only one probability for some formulations of the problem—the limit you want to place on missing a hot spot if it does indeed exist. The other error, saying a hot spot exists when it doesn't, cannot occur because we assume that if we do get a "hit" at one of the nodes, it is unambiguous (we hit a hot spot). We define hot spots as having a certain fixed size and shape, i.e., no amorphous, contouring hot spots are allowed. The hot spot problem is not a test of a hypothesis. Rather, it is a geometry problem of how likely it is that you could have a hot spot of a certain size and shape fitted within a grid, and none of the nodes fall upon the hot spot.

All the input dialog boxes for of the Hot Spot problem will not be shown in this user's manual. VPS's **Help**, and the textbook *Statistical Methods for Environmental Pollution Monitoring* (Gilbert 1997) are good resources for a complete discussion of the Hot Spot problem. We demonstrate a common formulation of the problem—find the minimum number of samples to find a hot spot of a certain size, with specified confidence of hitting the hot spot.

Problem Statement: A site has one Sample Area of one acre (43,560 square feet). We wish to determine the triangular grid spacing necessary to locate a potential circular pocket of contamination with a radius of 15 feet. We desire the probability of detecting such a hot spot, if it exists, to be at least 95%. The fixed planning and validation cost is $1,000. The field collection cost per sample is $50, and the laboratory analytical cost per sample is $100. Assume that the budget will be provided to support the sampling design determined from these requirements.

Case 9: We assume that the assumptions listed in Gilbert (1987, p. 119) are valid for our problem. We specify a hit probability of 95%, a shape of 1.0 (circular), and a radius (Length of Semi-Major Axis) of 15 feet. We will let VSP calculate the length of the side of the equilateral triangular grid needed for these inputs.

VSP Solution 9: First, open the file *OneAcre.vsp* using VSP Main Menu option **File > Open Project.** This is a VSP-formatted project file and it contains a previously defined Sample Area of the entire acre. Next, from the VSP Main Menu select **Sampling Goals > Locating a Hot Spot > Assume no false negative errors.** A grouping of the input dialogs for the four tabs: **Locating Hot Spot, Grid, Hot Spot, and Costs** are shown in Figure 3.29.

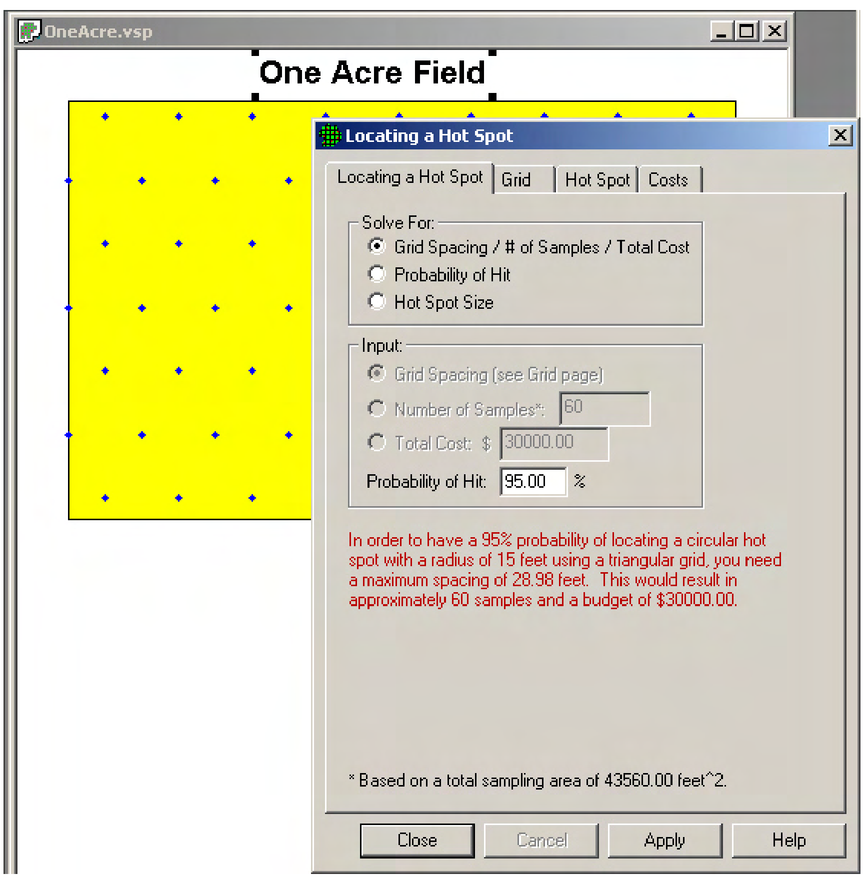


Figure 3.28. Input Boxes for Case 9 for Locating a Hot Spot

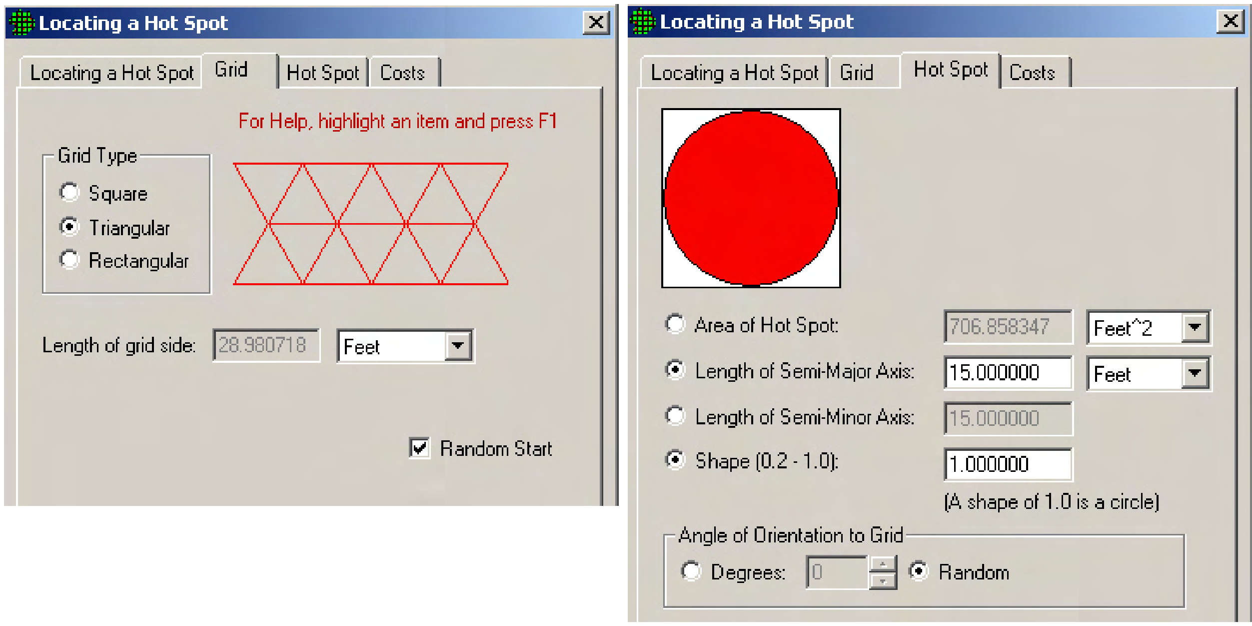


Figure 3.29. (contd)

The recommended length of grid side is shown in the dialog box for **Locating a Hot Spot**, Solve for **Grid Spacing**. It is about 28.98 feet or, rounding up, a 30-foot triangular grid.

Note: For this set of inputs, VSP will always give the length of the triangular grid as 28.98 feet. The *Calculated total number of samples* in the **Report View** is always 60 for this set of inputs. However, the *Number of samples on the map* changes as you repeatedly press the **Apply** button. This occurs whenever the **Random Start** check box in the dialog box tabbed **Find Grid** is checked. Because the starting point of the grid is random, the way in which the grid will fit inside the Study Area can change with each new random-start location. More or fewer sampling locations will occur with the same grid size, depending on how the sampling locations fall with respect to the Sample Area's outside edges.

The input dialog boxes and report for the hot spot problem have some unique features:

- Placing the cursor in the **Length of Semi-Major Axis** on the **Hot Spot** tab and right-clicking displays a black line on the picture of the circle for the radius.

- **Shape** controls how "circular" the hot spot is. Smaller values (0.2) result in a more elliptical shape; 1.0 is a perfect circle.

- The user can specify the **Area** of the hot spot or the **Length of the Semi-Major Axis.** Both fields have pull-down menus for selecting the unit of measurement.

- The Report provides additional information on the design such as the number of samples (both "on the map" and "calculated") and grid area.

The Hot Spot Sampling Goal takes into account the **Total Area to Sample** (see this field on the **Cost** tab) when calculating total number of samples. Many of the other designs use the standard deviation to control sample size.

Selecting **Sampling Goals > Locating a Hot Spot > Account for false negative errors** provides an option for entering a false negative rate for each sample (the probability each contaminated sample will not be detected).

3.2.9 Find UXO Target Areas

This Sampling Goal originated from specific unexploded ordinance (UXO) problems faced by the Department of Defense. The sampling designs the VSP developers came up with to address these problems are somewhat specialized. UXO methods are covered in Chapter 7.

3.2.10 Access Degree of Confidence in UXO Presence

This Sampling Goal also orginates from UXO Problems, and is covered in Chapter 7.

3.2.11 Non-statistical Sampling Approach

VSP allows the user to directly place samples in a Sample Area without going through the Sampling Goals and the DQO Process. If the user has a pre-determined number of samples, possibly obtained from a prior DQO study, VSP allows the user to input a sample size and place the samples within the Sample Area using either a random design or a systematic design. Menu selection **Sampling Goals > Non-Statistical Sampling Approach > Predetermined Number of Samples** brings up a simple dialog box where the user can input any value for **Number of Samples**, and by hitting the **Apply** button, the samples are placed in the Sample Area according to the design specified (random or systematic).

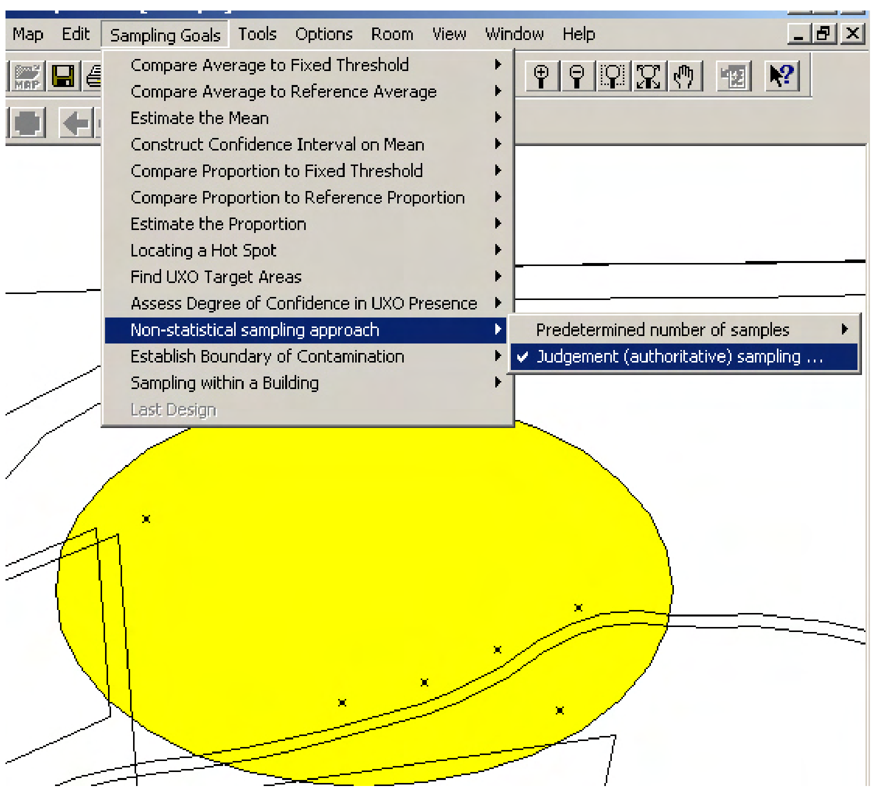


Figure 3.30. Judgment Sampling with 6 Sampling Locations Added Manually

VSP allows user to manually place samples on a Map within a selected Sample Area using menu selection: **Sampling Goals > Non-Statistical Sampling Approach > Judgment (authoritative) Sampling**. This option is available only if

View>Map is selected and a Sample Area defined. Judgment Sampling is a toggle switch. When it is turned on, any time the user clicks on the map, a sample marker is placed at that location. Judgment samples can be added to a blank Map or to an existing design. The Type is "Manual" (see **View > Coordinates**). Manual samples may also be added by typing the coordinates (x, y) on the keyboard.

In Figure 3.31, 6 samples have manually been added using Judgment Sampling.

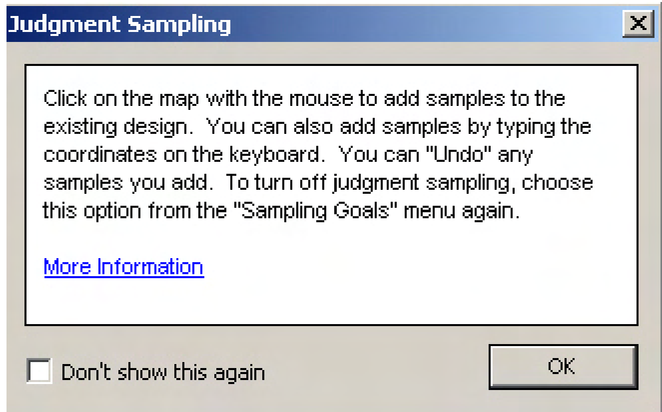


Figure 3.31. Judgment Sampling with Six Sampling Locations Added Manually

3.2.12 Establish Boundary of Contamination

Finding the boundary of contamination is a problem faced by Department of Defense remediation managers. Training ranges or areas where the soil is known to contain explosive residues (or other contaminants of concern) may have boundaries that completely or partially enclose the contaminated area. Sampling is required to determine whether contamination has breached a known boundary line and if so, determine the correct boundary line. VSP has a special module for this sampling problem. The problem and the VSP solution are described in *Visual Sample Plan User's Guide for Establishing the Boundary of Contamination*, R.O. Gilbert, et al, PNWD-3580, 2005, which can be downloaded from the VSP web site **http://dqo.pnl.gov/VSP**. In this User's Guide we will provide a summary description of the VSP boundary module.

The VSP sampling design for this problem involves taking a representative sample (called a multiple increment or MI) for each segment along the known, user-input boundary. If the one or more samples show contamination, extend or "bump out" the boundary, and take more samples. The boundary continues to be bumped out until all samples taken along the new boundary line are "clean".

In Sections 2.3.1.1 and 2.3.1.2 we described how to define enclosing and partial boundaries in VSP using **Edit >Sample Areas > Define New Sample Area,** and **Edit > Sample Areas > Define New Open-Type Sample Area,** respectively. VSP determines the number of segments using the length of the boundary and the specified width of a contaminant plume (hot spot) that would be of concern if it is present at the boundary or extends beyond the boundary line. VSP calculates the optimum segment length (OSL) along the current boundary, where all segments have the same length. One or two MI samples are collected per segment. VSP assumes that each MI sample collected in a segment consists of 25 small soil samples (increments) that have been collected in sets of 5 small samples clustered around each of 5 equally spaced Primary Sampling Locations along the segment. The spacing of the five segments depends on the specified width of the hot spot of concern at the boundary**.** The OLS is calculated as 5 times the user-specified width of the contamination plume (hot spot) of concern.

VSP provides two versions of the design: one for enclosing boundaries and one for partial (open-type) boundaries. Partial boundaries represent a dividing line, with contamination on one side and no contamination on the other side. VSP provides special tools for creating and manipulating open-type sample areas.

3.2.12.1 Enclosing Boundary

Menu selection **Sampling Goals > Establish Boundary of Contamination > Enclosing Boundary** brings up the dialog box in Figure 3.32 for tab **Enclosed Boundary Sampling.** The first input required is the confidence needed that the mean calculated from limited sample data is indeed less than the action limit. For this example, that confidence level is **95%.** The diameter of the area of contamination (i.e., the hot spot) that the user wants to be sure is detected at the boundary is input as **45 ft**. The next box, labeled Duplicate Requirements, has to do with how many of the segments need duplicate MI samples to be collected. VSP requires that: at least 5 segments; or at least 10% of the segments, need duplicates. The user may select which requirement is used. While **10%** is the minimum, the user may input any percentage for duplicates.

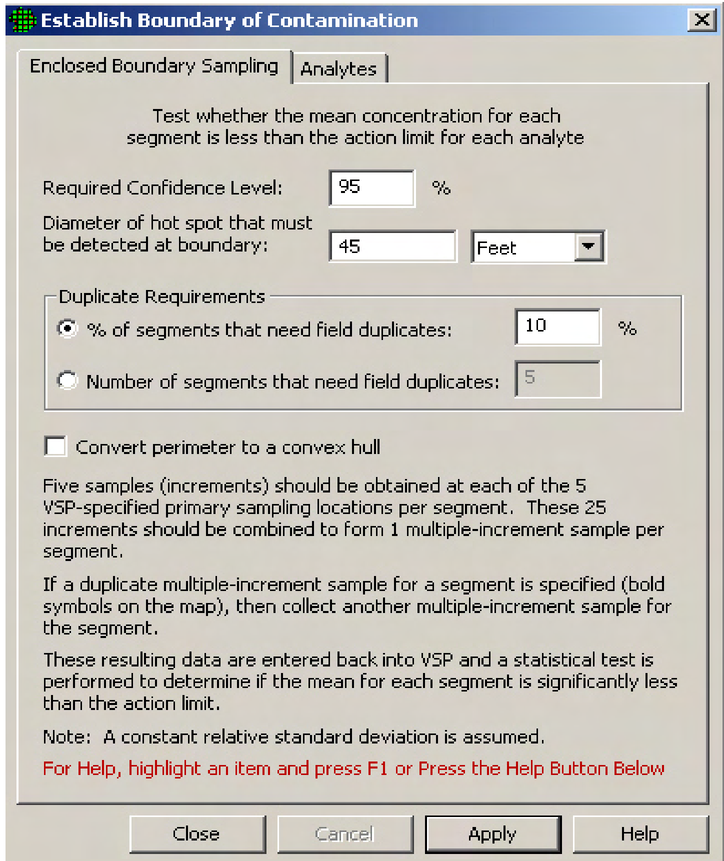


Figure 3.32. Dialog Box for Entering Design Inputs for Sampling an Enclosing Boundary

Note: The purpose of duplicate MI samples is to estimate the relative standard deviation of the data so that an Upper Confidence Limit (UCL) test can be conducted for each segment. See VSP Help for more information.

If the boundary of the site is very irregular, e.g., has various indentations, the VSP user can specify in the dialogue box that VSP should change the boundary to a **convex hull**. This has the effect of smoothing out the boundary irregularities, but it also enlarges the area enclosed by the initial boundary. In practice, the VSP user can try this option and view the resulting initial boundary to see if the new boundary is acceptable. In Figure 3.32 we leave this box unchecked.

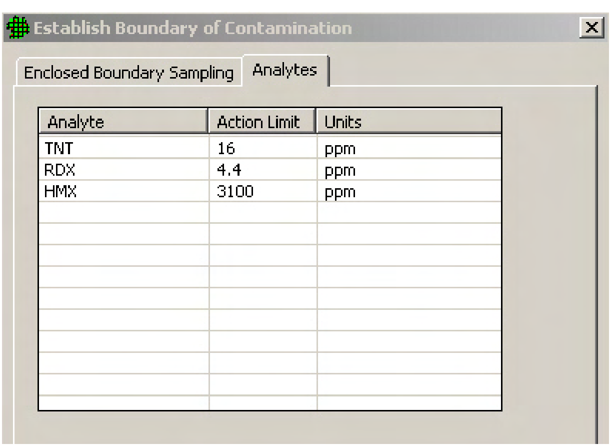


Figure 3.33. List of Default Contaminants of Concern and their Action Levels

The user now must input the contaminates of concern and the threshold (action level) at which we want VSP to trigger extending the contamination boundary line. The dialog box for tab **Analytes** is shown in Figure 3.33. VSP provides a default list of contaminants of concern (TNT, RDX, and HMX) and a default list of upper limit values (Action Limit) for each (16ppm, 4.4ppm, and 3100ppm). To remove a contaminant from the list, erase the name and the limit. To add a contaminant, enter its name and threshold value in the blank lint below the last contaminant.

For the Millsite.dxf map file selected, and the central ellipse in the center of the map selected as the Sample Area with an enclosing boundary, we see in Figure 3.34 that after clicking the **Apply** button in the previous screen, VSP divides the boundary into 12 segments. Shown are the 5 equally-spaced Primary Sampling Locations in each of the segments. The segments for which the Primary Sample Locations are in **bold** type will have duplicate samples taken at each location. Different symbols are assigned to each segment to differentiate the segments visually. For each segment, VSP assumes the user will form the MI sample for that segment by mixing 5 small soil samples collected from each of the 5 Primary Sampling Locations. Hence, each MI sample is formed from the 25 small soil samples.

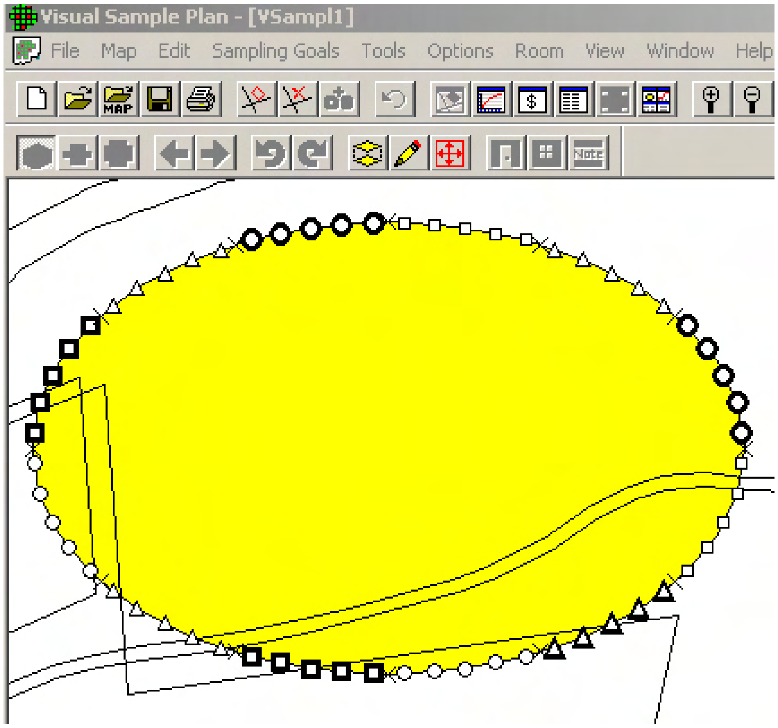


Figure 3.34. An Enclosing Boundary Showing the Five Primary Sampling Locations for Each of the 17 Segments

The user now collects the samples, mixes the samples to form a representative MI sample for each segment, and measures each MI sample. The results are input into VSP using the **Sample Information** box that appears when the cursor is placed over one of the Primary Sample Locations, and right-click the mouse. Use the keyboard to enter the measurement value into the appropriate row in the column labeled "Value" in the **Segment Sample Results** sub-box. Use the down arrow button on the keyboard to move between rows within the sub-box. Figure 3.35 shows the Sample Information Box.

We happened to click on a segment for which two MI samples are required. Thus, we will need to input two sets of measurements, one for each of the 3 analytes, making 6 input values required. Click the **OK** button on the dialog box to close the **Sample Information** box for that segment. Repeat the above process for each of the segments to enter all the measurement values. The **Segment Sample Results** box has a column headed "UCL". VSP will fill in this box with the Upper Confidence Limit on the mean once all the measurement values for the segment are input. The UCL is used to test whether the mean exceeds the action level for that segment.

Sample results can be entered into VSP using software such as a spreadsheet. Consult VSP's **Help** for instructions on this process.

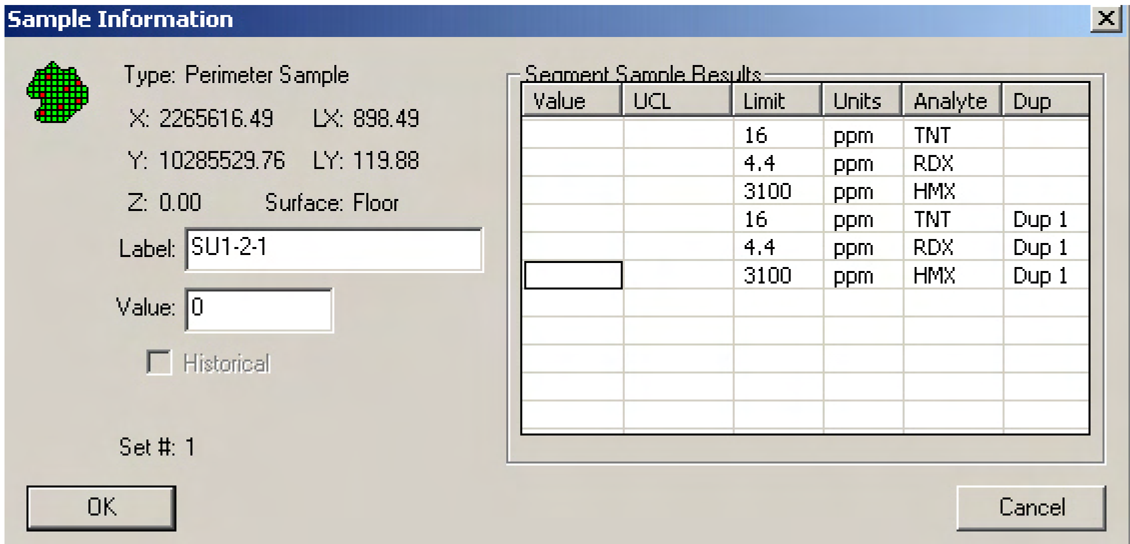


Figure 3.35. Sample Information Box for Entering Data into VSP, Duplicate Samples Required

VSP now tests whether each boundary segment should be enlarged (bumped out). This is described in an Appendix to the report PNWD-3580 referenced above. In Figure 3.36 we see an example of two expanded boundaries. Note the red colored Primary Location Segments indicate that segment did not pass the UCL test and hence had to be “bumped out”.

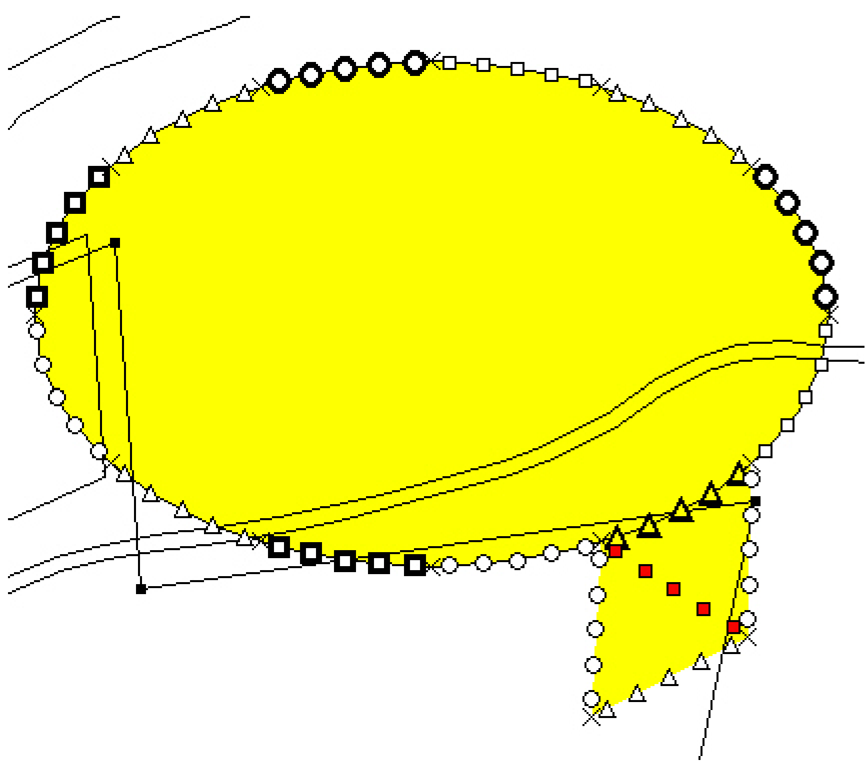


Figure 3.36. Enclosed Boundary with Two Bumped-Out Segments

3.2.12.2 Partial Boundaries

The input screens, the dialog boxes, and the maps for Partial Boundaries problems are similar to those for the Enclosed Boundaries and will not be shown here. For a discussion of the Partial Boundaries problem consult the VSP Help function.

3.2.13 Sampling Within Buildings

While many of the sampling designs presented in earlier sections could be applied to 3-dimensional sample areas such as building and rooms (-- as opposed to 2-dimensional sample areas such as land areas), the sampling designs provided under Sampling within a Building are uniquely suited for problems where contamination is released into an enclosed structure and contamination can be on walls and ceilings, windows and doors, as well as on floors. Many of the VSP features added for this module were requested by the Department of Homeland Security (DHS), Combating Terrorism Technology Support Office. DHS wanted ways to sample walls, floors, ceilings, and other surfaces to determine if contamination is present, its magnitude and extent throughout the building, and after decontamination to see if the decon was effective. The sub-goals within this section work through various scenarios when a chemical, biological or radionuclide release has occurred within a building, and contamination may be: isolated; microscopic; pose a health risk at very low levels of contamination; selectively adheres to surfaces and crevices; capable of being spread throughout the building; and generally from an unknown source and released in an unknown location within the building. The unique nature of these contamination scenarios requires unique sampling methods and unique analysis methods.

Figure 3.37 is a schematic of the menu options available under the sampling goal of Sampling within a Building.

In the case of a terrorist bio/chem/rad event, the parameters of interest will most likely be the mean, maximum, or a percentile of the distribution of all possible measurements. So the first major branch in the menu tree is whether a decision on contamination will be made based on the mean/average, on individual measurements, or on a combination of both. Depending on which branch is selected, very different menu options will be offered, very different sampling designs will be suggested, and very different comparisons and analyses will be performed.

In the sections below, we will provide a brief discussion of each of the end points (i.e., VSP-recommended sampling designs) for the menu tree in Figure 3.37. Some of the designs in the tree have been recommended for other sampling goals in VSP and have been discussed in earlier sections of this manual. Consequently, in this part of the manual we will focus the discussion on the designs that are unique to Sampling within a Building. For selected designs (Figs 3.38b and 3.40b), we show the samples located within simple rooms that we drew in VSP so the user can see how VSP places samples (both point samples and grid samples) on the floor, ceiling, walls, windows and doors of a room.

Several papers and presentations have been published on the designs and analyses associated with Sampling within a Building. In addition to the technical discussions found in the VSP online Help for each design, consult the VSP web page (**http://dqo.pnl.gov/VSP**) for papers and presentations on the theory behind the designs and data analyses. A complete technical discussion and verification of all tests, sample size calculations, and algorithms used in Sampling within Buildings can be found in *Technical*

Documentation and Verification for the Buildings Module in the Visual Sample Plan (VSP) Software, Gilbert et al., PNNL-15202, available for download on the VSP web page.

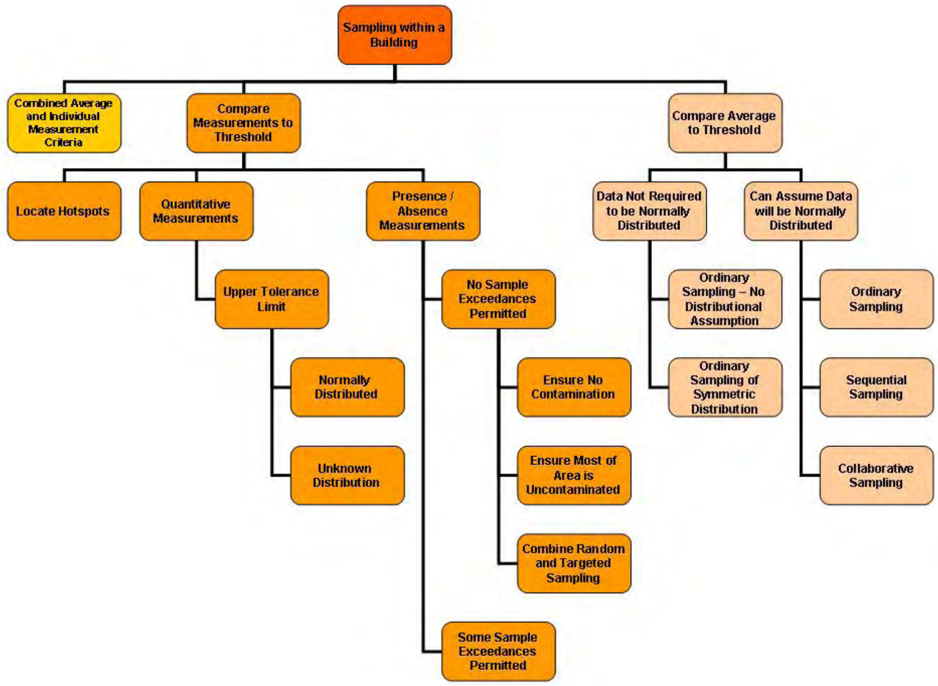


Figure 3.37. Menu Structure of Options Under Sampling Goal of Sampling Within a Building

3.2.13.1 Compare Average to a Threshold

A threat analysis team would be interested in average contamination within a building or room if there were multiple releases and subsequent spread of contamination, and the primary exposure scenario concerned an accumulated dose, or a long-term exposure of individuals randomly moving about within the room/building. The sampling goal would be to take samples and compare the average contamination in a room, or a group of rooms, to a health risk-based threshold.

A number of statistical sampling designs could be applicable depending on the assumptions, constraints, and sampling technologies. These designs include simple random sampling, grid sampling, sequential sampling, and collaborative sampling. Similarly, a number of tests could be conducted on the data to decide if the mean is greater than a threshold. These tests include the one-sample t test, a sign test, or a ranked sum test. All the designs within this sampling goal have been discussed earlier in the manual under the sampling goal of Compare Average to Fixed Threshold (Section 3.2.1).

3.2.13.2 Compare Individual Measurements to a Threshold

Most biological, chemical, or radiological threats involve a risk to an individual if any exposure to the contaminant is encountered. As such, there is an interest in individual (rather than average) measurements. If the entire area/decision unit cannot be surveyed, the goal may be to take limited samples and based on those samples, make statements (with the associated confidence level) about unsampled areas. Another goal might be to make a confidence statement about the percent of the total population that is contaminated, based on sample data. For each goal, one of the VSP outputs is a statement that can be made based on sample results. For example, for the sampling goal **Sampling within a building > Compare measurements to threshold > Presence / absence measurements > No sample exceedances permitted > Ensure most of area is uncontaminated**, after providing the required input, and taking the appropriate number of samples, taken at the VSP-specified locations, VSP would provide the following concluding statement:

Since none of the samples taken contain contamination, then you can be 100P% confident that less than p% of the possible grids in the total population (Sample Area, decision unit) contain contamination.

Some of the designs in this section are new to the current release of VSP and unique to the Sampling within a Building goal. Others have been recommended for other VSP sampling goals, but their application to the contaminated building scenario is unique.

3.2.13.3 Detect Hot Spots

The 3-dimension scenario for the hotspot problem is that the user is concerned about hotspots on ceilings as well as on floors and walls. The extension from the 2-dimensional problem is straightforward. The floor, ceiling and wall-strip (wall sections laid edge-to-edge) represent three independent surfaces that might contain a hotspot. Refer to Section 3.2.8 Locating a Hot Spot for a discussion of this sampling goal.

3.2.13.4 Ensure Most of Area is Uncontaminated

There may be occasions when the type, duration or magnitude of decontamination or other response activities in a building will depend on how much of a room or set of rooms is contaminated above some action level (AL). If some small amount of contamination in a building is within the acceptable risk levels, then a goal of sampling may be to be able to make statements such as “based on our limited sampling, we are 95% confident that no more than 3% of the room is contaminated”. Or our goal may be to say “based on our sample results, we are 99% confident that no more than 10 of the total possible 1000 grid locations in the room are contaminated”. In both cases, we take samples, and based on how many samples test above the action level, make statements about the overall contamination in the room or building.

The first branch in the tree under **Ensure Most of the Area is Uncontaminated** asks the user to select:

- Upper tolerance limit (UTL) , or
- Acceptance Sampling (AS)

The major distinction between selecting UTL or AS is whether the total number of sample locations in the decision unit/sample area (e.g., room, building, structure) could be considered to be infinite (- then use UTL methods) or finite (- then use AS methods).

If the decision unit is large, and the sample support (the amount of material contained in the sample, or the area swiped for a sample) is small, then point samples are taken under the assumption of an infinite population of possible sample locations. The assumption of an infinite population eliminates the need for a finite population correction factor in the sample size calculation. It also eliminates the need to consider sampling with or without replacement. Random points are generated in the decision unit and samples are taken at those points.

Methods associated with infinite populations are concerned with percentiles of a population. To test the null hypothesis that the decision unit is contaminated, we say that if the upper confidence limit on a percentile of the population is less than the limit, then we can reject the null hypothesis and conclude the decision unit is uncontaminated. A confidence interval on a percentile of a population is called a tolerance interval. The tests in this group calculate an Upper tolerance limit (UTL) for the population and compare it to a limit. The UTL is calculated from sample results. The methods of Upper tolerance limit are used for infinite populations.

If the decision unit (i.e., a room) is small relative to the sample support, and the sample support is well-defined (say the sample will consist of a 4 inch square swab), then samples are taken under the assumption of a finite population of all possible sample locations. We would partition the room into individual, non-over-lapping "grid" locations, specify the total number of grids in the room, specify the number of grids to be sampled, then use a random selection of size *n* (calculated by VSP) grids to be included in the sample.

Methods associated with finite populations use the concept of "lots", i.e., a discrete group of units extracted from a total production run. This has application to a decision unit that can be gridded, with each grid unit having a discrete identity within the larger population. The methods of Acceptance sampling (taken from industrial quality control) are used for finite populations. The tests in this group of methods count the number of grids in the sample that exceed an action level (are defective) and as long as that number is less than or equal to an "Acceptance Number", we say the level of contamination is within the tolerable (i.e., acceptable) limits.

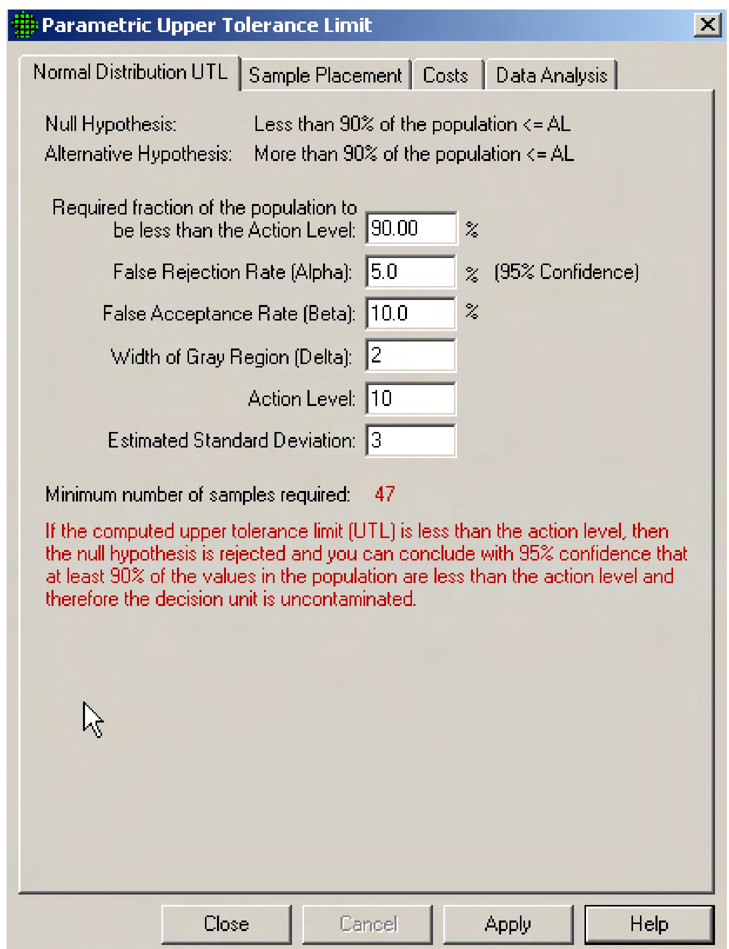


Figure 3.38a. Dialog Input Box for Comparing Percentile of Normal Distribution to Action Level

Sampling Goals > Sampling within a Building > Compare measurements to threshold > Quantitative measurements > Upper tolerance limit > Normally distributed

If the distribution of measurements of contamination at all possible point sample locations in the decision unit can be considered to be normally distributed (i.e., the standard bell-shaped curve), we can use the formula that calculates the UTL of a percentile of the normal distribution in the test of the null hypothesis. This UTL will be compared to the Action Level to determine whether we accept or reject the null hypothesis. The UTL formula will also be used in the calculation of the sample size, *n*. Figure 3.38a shows the dialog box for this sampling goal.

The null hypothesis being tested is that the true P^{th} percentile of the population exceeds a fixed Action Level (i.e., the decision unit is contaminated). The user is asked to input the smallest fraction of the population required to be less than the Action Level in order for the unit to be considered uncontaminated, input here as **90%.** Note: none of the designs discussed below use the Action Level in the sample size calculation, but Action Level is used in performing the Tests under the Data Analysis tab (see Section 5.6 on Data Analysis). The next set of inputs are the DQO inputs required to calculate sample size. These inputs are defined in Section 3.2. The **Help** brings up a screen that describes how these inputs are used to calculate *n*. VSP calculates that **47** samples are required to execute the test of the hypothesis with the set of DQOs listed.

In Figure 3.38b we see the **47** samples located in a room. We drew a room, supplied the inputs for the Dialog Box, and hit the Apply button. We select **View > Room** to see the samples located in the room.

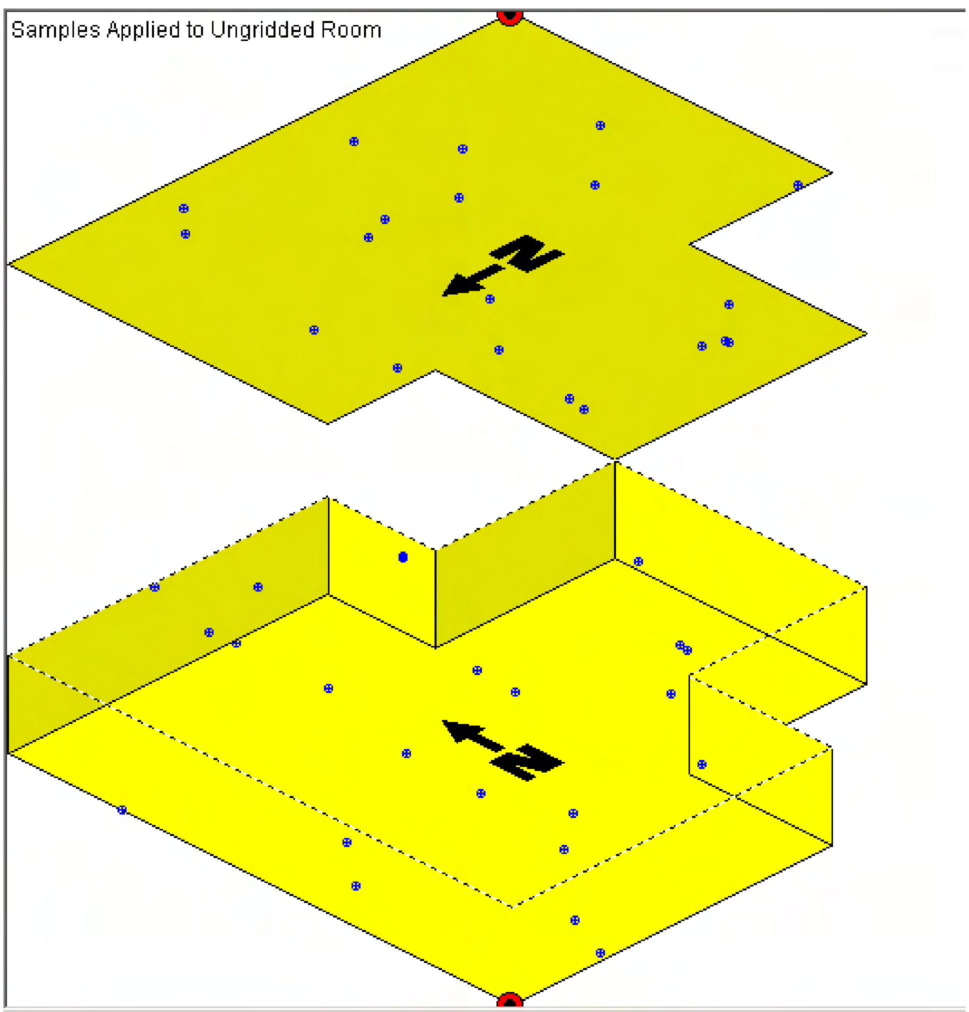


Figure 3.38b. Samples Placed on Floor and Ceiling Within a Room

Sampling Goals > Sampling within a Building > Compare measurements to threshold > Quantitative measurements > Upper tolerance limit > Unknown distribution

If the distribution of measurements is unknown, we must calculate a non-parametric UTL for use in the test of the hypothesis that the true Pth percentile of the population exceeds a fixed Action Level. The non-parametric UTL happens to be the largest measurement of the *n* samples taken, where *n* is calculated using the DQO inputs in Figure 3.39 and the sample size formula discussed in the VSP Help for this input screen.

VSP calculates that we need to take **29** samples in order to make a **95%** confidence statement about the **90th** percentile of non-parametric distribution. The exact wording of the conclusion that can be drawn is one of the outputs of VSP. An example conclusion is shown in red in Figure 3.39.

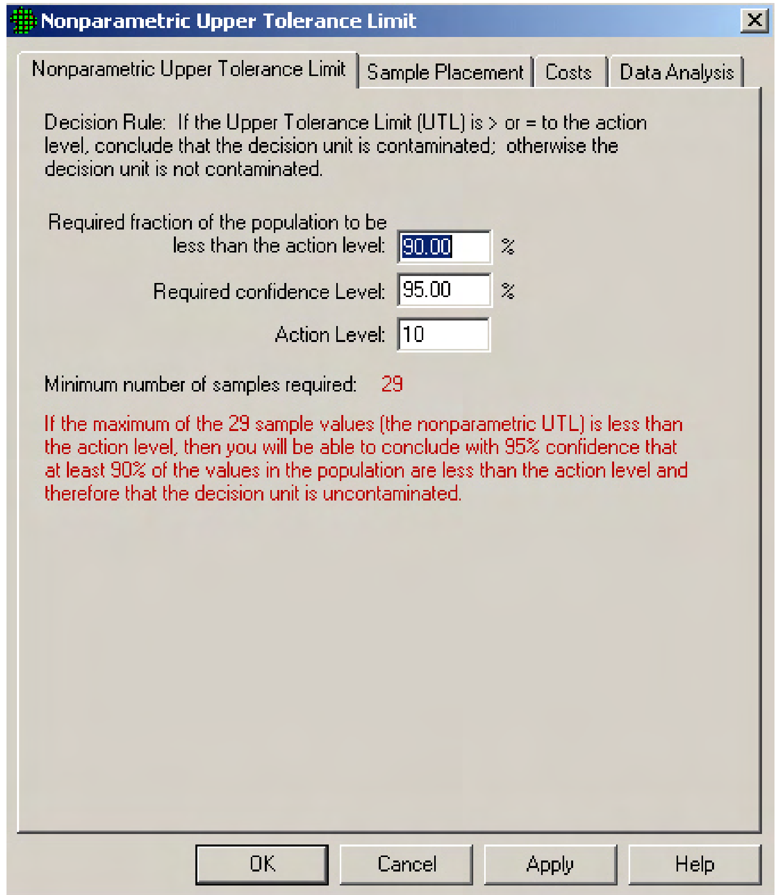


Figure 3.39. Dialog Input Box for Comparing Percentile of Unknown Distribution to Action Level

Sampling Goals > Sampling within a Building > Compare measurements to threshold > Presence / absence measurements > No sample exceedances permitted > Ensure most of the area is uncontaminated

If the VSP user's goal is to specify a proportion defective (called Pd in the Help) which is the maximum tolerable proportion of defective (contaminated above the Action Level) grid units allowed in the population, and wants a high confidence in recognizing when that proportion is exceeded, then this sampling goal is selected. The tab for this sampling goal states that the user wants a "high confidence that few grids contain contamination". Again taken from quality control literature, the method VSP uses to calculate sample size is called "Compliance Sampling" or "Acceptance Sampling for C = 0". For this design, the Acceptance Number, C, which is the number of measured grid units in the sample that can exceed the Action Level (i.e., allowed to be defective) is zero. As shown in the Dialog Box in Figure 3.40a, for the user inputs of Action Level = **10**, total number of possible grids in the decision unit or room(s) = **1,000**, the maximum allowed % of grids in the decision unit that can contain contamination = **10%,** and the confidence required that the maximum % is not exceeded = **90%.** VSP calculates a sample size of *n*=**24**. VSP sets the Total Possible Number of Grids in Selected Rooms to 1000 when no

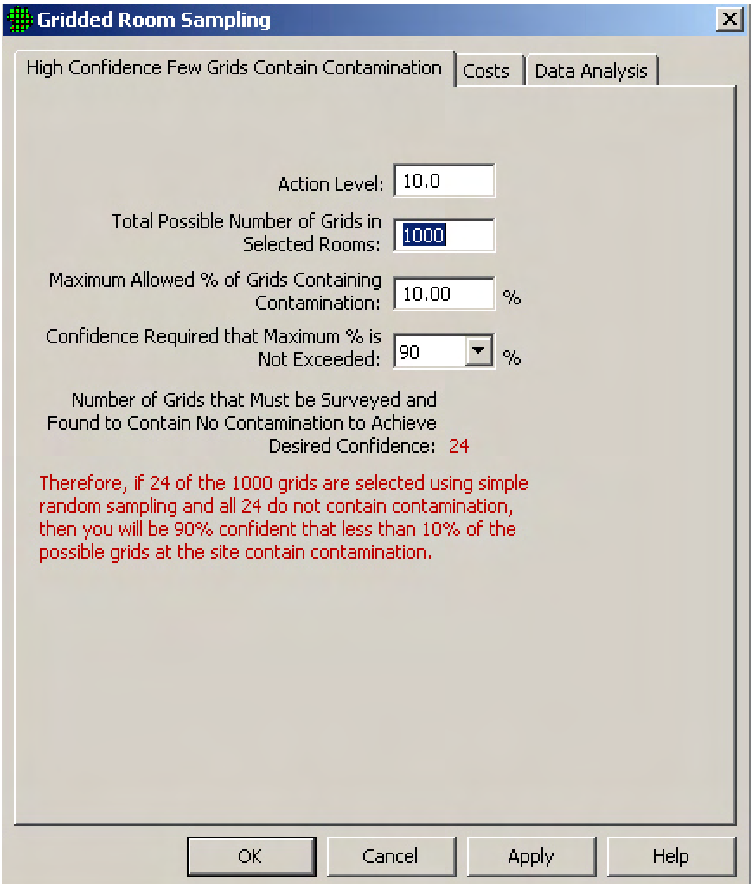


Figure 3.40a. Dialog Input Box for Compliance Sampling

Sample Area/Rooms have been selected. Users can input values of their own choosing for Total Number of Grids when designing sampling plans for items.

A scenario when Compliance Sampling may be applicable is that it is initially assumed that no contamination exists and the goal is to have a high confidence of detecting whether a specified Pd percent of the units in the decision unit are actually contamination. Shown in red in the Dialog Box, VSP reminds the user that for this design, none of the 24 grids may exceed the Action Level in order to be 90% confident that less than 10% of the population of all grids at the site contain contamination (i.e., above the action level).

Once a room or rooms have been drawn and selected, VSP shows the Length of Grid Side in the Dialog Box and calculates a Total Possible Number of Grids for the Sample Area/Rooms based on that grid size. Note: VSP initially calculates a default value for the Length of Grid Size. The user replaces the default value with a grid length that is appropriate for the type of sample that will be taken, e.g., a 1ft x 1ft square swath, a 4cm x 4cm swab. Hitting the Apply button on the Dialog Box places grids on the selected rooms, and calculates a new Total Possible Number of Grids based on this new grid size.

In Figure 3.40b we see an example of a 1ft x 1ft grid applied to a room that has two closed windows (so samples can be placed on them) and an open door (so samples cannot be placed on it). VSP calculates that **7,284** possible grids of 1ft x 1ft could be placed in the selected room, **24** of which will have samples collected from them. Refer to Section 6.3 on types of objects that can be placed within rooms for an explanation of windows and doors within rooms.

Sampling Goals > Sampling within a Building > Compare measurements to threshold > Presence / absence measurements > Some sample exceedances permitted

For this sampling goal, the user specifies two proportions: Po, the maximum acceptable proportion of units in the population that are allowed to be contaminated above the Action Level; and Pa, the unacceptable proportion of units in the population that are contaminated above the Action Level. If the number of grid units in the sample that have contamination greater than the Action Level exceeds the Acceptance Number, C (which VSP calculates), then the user concludes the maximum acceptable % of grids contamination has been exceeded and the real proportion defective is equal to or greater than Pa. The method used for this design is called "Acceptance Sampling for C > 0", or just "Acceptance

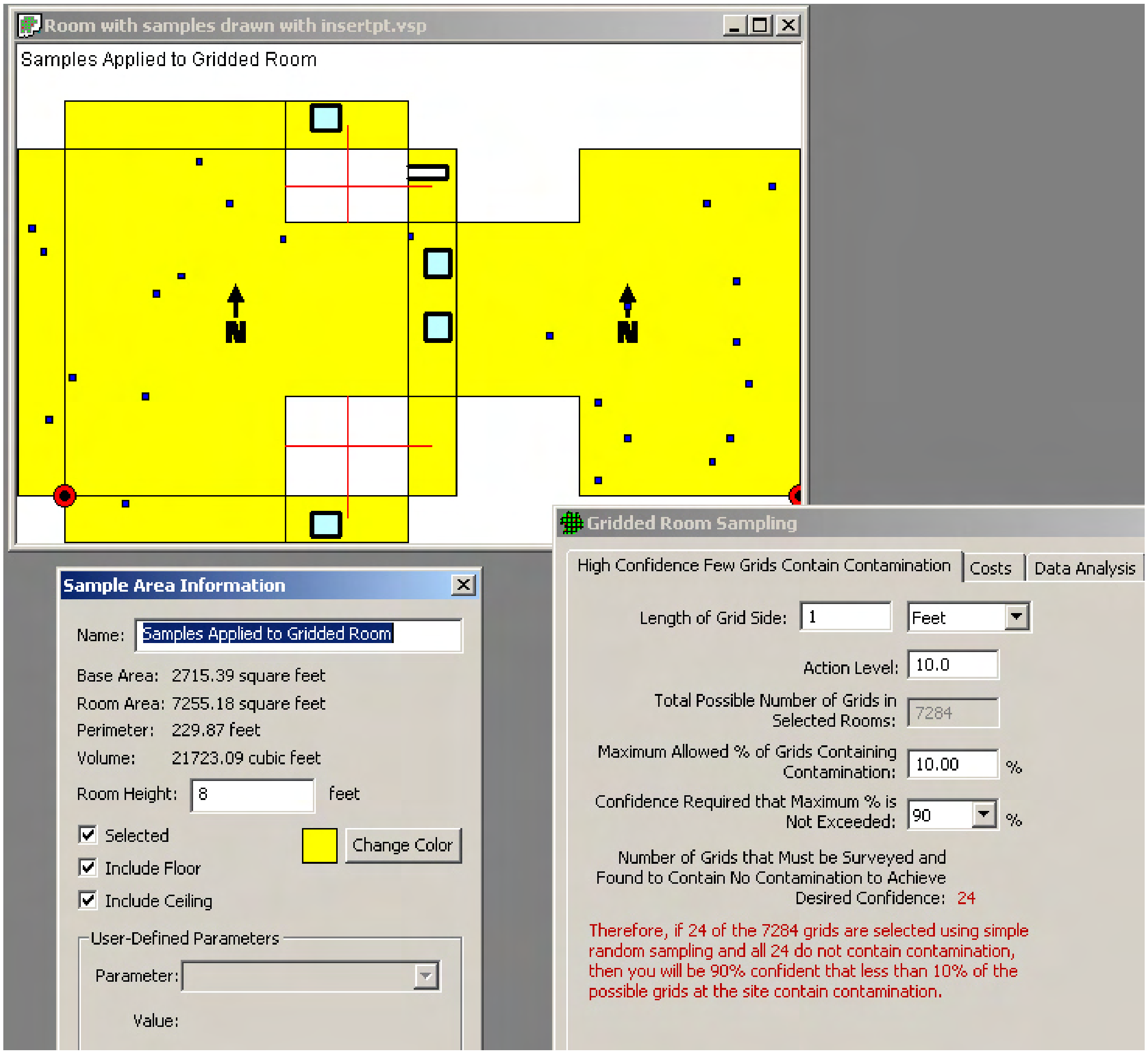


Figure 3.40b. Room with Samples Placed on Floor, Ceiling, Walls, and Windows

Sampling". Note that this method is slightly different from the previously discussed method of Compliance Sampling. Compliance Sampling made a confidence statement about the proportion defective, Pd. Acceptance Sampling is a test of hypothesis between two different statements about the number of defective units in the population, Do and Da (Da > Do). Therefore, Acceptance Sampling for C > 0, requires both an Alpha and a Beta (see Section 3.2). Refer to the Help for a more complete discussion of the method.

A scenario when Acceptance Sampling for C > 0 may be applicable is that you know some level of contamination may exist (naturally occurring, or the level of contamination is at the detection level of the monitoring equipment) to give a lower bound Po. There is an upper bound Pa where a health risk may occur and you want to be have a high confidence of detecting contaminating greater than Pa percent.

The Dialog Input Box for this sampling goal is shown in Figure 3.41. We are asked to input the total number of grid units in the population, shown here as **1,000**. Next we input the Action Level and the DQO inputs needed to calculate sample size and the Acceptance Number, C. The acceptable % of grids allowed to be contaminated is **5%** (i.e., Po). Do is shown as **50** (5% times 1,000). Next we input the unacceptable % of grids allowed to be contaminated as **20%** (i.e., Pa). The next two inputs are the decision error rates, Alpha (**5%)** and Beta (**10%).**

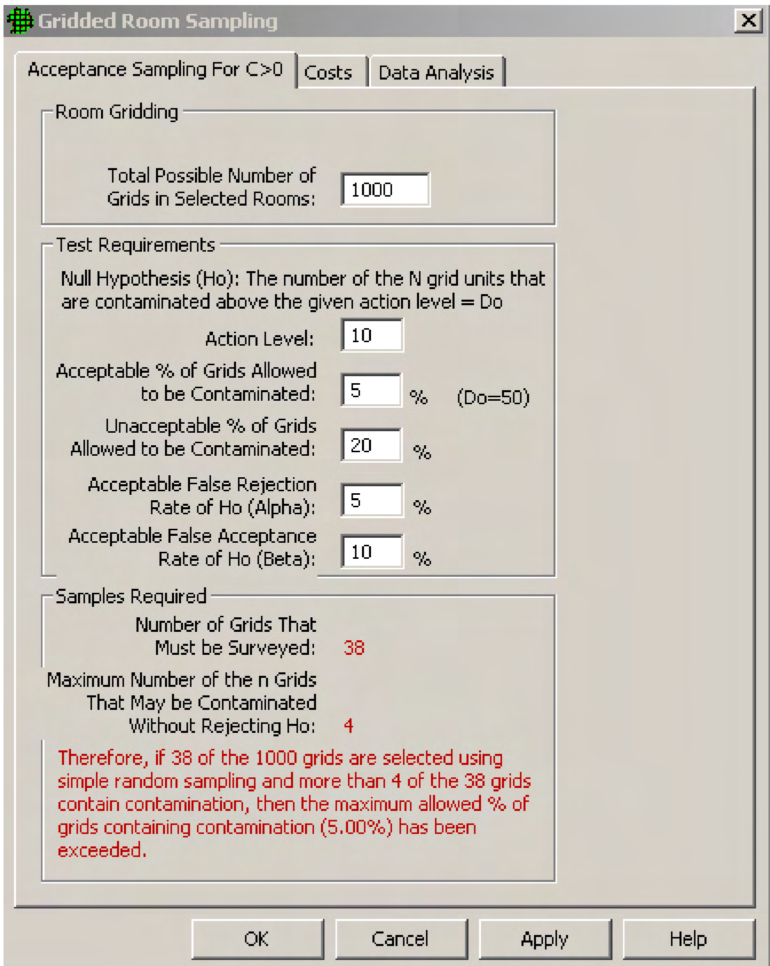


Figure 3.41. Dialog Input Box for Acceptance Sampling for C>0

VSP now calculates n = **38** as the number of grids that must be sampled out of the total population of N=1,000 grids. VSP also calculates the Acceptance Number of C = **4**. VSP provides a statement of the test criteria for accepting or rejecting the null hypothesis, shown here in red: if more than 4 of the 38 grids sampled contain contamination, then we can reject the statement that 5% or less of all possible grids contain contamination.

3.2.13.5 Ensuring No Contamination Exists in the Decision Unit

The final design under the sampling goal of **Comparing measurements to threshold** is when the VSP user wants to have a high degree of confidence that no contamination exists in the decision unit. As would be expected, this design is very sample intensive. This method, known as the "Wright/Grieve" method, was named after its developers T. Wright and A.P. Grieve. The method relies on input from the user as to a priori beliefs on the presence or absence of contamination in the decision unit. In Figure 3.42 we see the inputs required for this design.

After inputting the total possible number of grids N=**1,000**, and the Action Level = **10**, the user inputs the required confidence for concluding no contamination exists as **95%.** From the pull-down list, the user selects that there is a **Extremely Low Percentage** prior belief that any of the 1,000 grids in the population contain any contamination above the action level. VSP translates that mean we expect **.1%** or less of all possible grids to be contaminated. To achieve these inputs, VSP tells us we have to sample **901** of the 1,000 possible grids and **none** of the sampled grids can contain contamination greater than the action level to be 95% confident that none of the possible grids at the site contain contamination. If we have no prior knowledge and input the Prior Belief as Unknown Percentage, VSP would tell us we need to sample 950 grids and find no contamination.

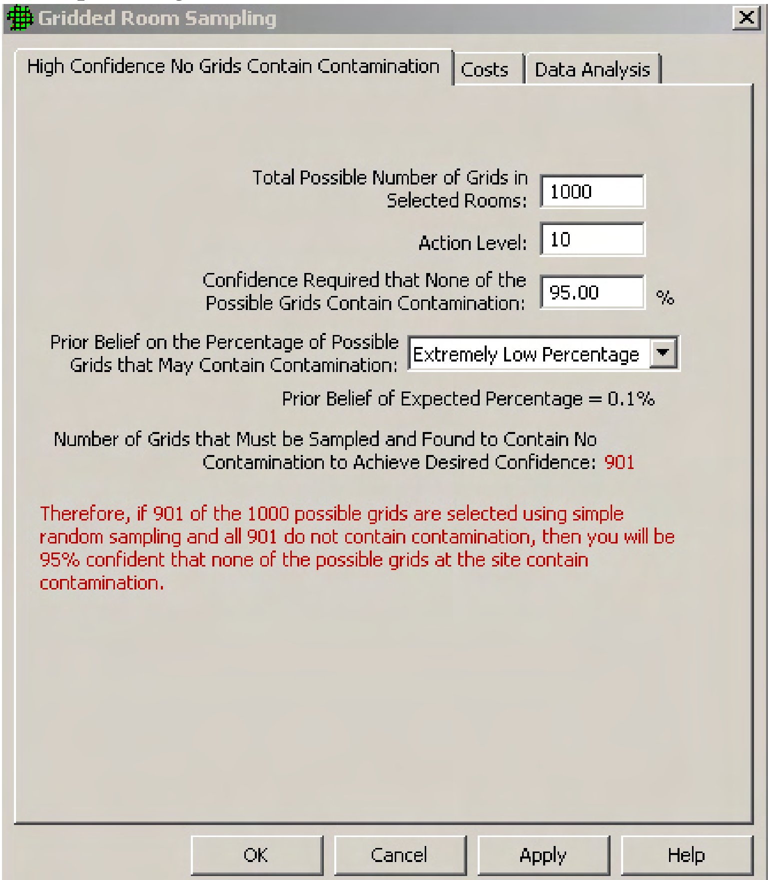


Figure 3.42. Dialog Input Box for High Confidence No Grids Contain Contamination

3.2.13.6 Combined Average and Individual Measurement Criteria

In many of the scenarios associated with contamination within a building, the user may be concerned about average contamination greater than a threshold for purposes of assessing chronic exposure of individuals to contamination over an extended period of time and over broad areas, yet also want to be assured that no individual measurement exceeds a different threshold. Or the user may want to be assured no hotspots of a certain diameter exist, and that no individual measurements exceed a threshold. The user wants to take enough samples to meet both goals, so the sample size taken will be the larger of that required by either design. The larger-than-required sample size for the smaller design will result in improved performance, such as

- a smaller Beta error rate, applicable for most of the testing designs (e.g., One Sample T, WRS),
- a higher-than-requested confidence for the Nonparametric UTL design, and
- a smaller size for a detectable hot spot for the Hot Spot design.

VSP back-calculates these performance variables for the larger sample size and displays the new values for the performance variables in the Dialog Box(s).

Figure 3.43 shows the Dialog Box for choosing the two designs for the Combined Design Goal.

Figure 3.44 shows the pull-down list of available designs in VSP for the first goal, Compare Average to Threshold.

Once a Compare Average to Threshold design is selected for the first goal, a design is selected for the second goal, Compare Individual Measurements to Threshold.

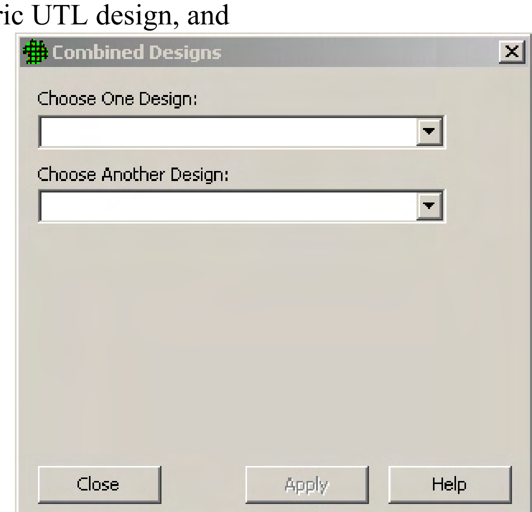


Figure 3.43. Dialog Box for Selecting Combined Designs

Figure 3.45 shows the pull-down list of available designs in VSP for Compare Individual Measurements

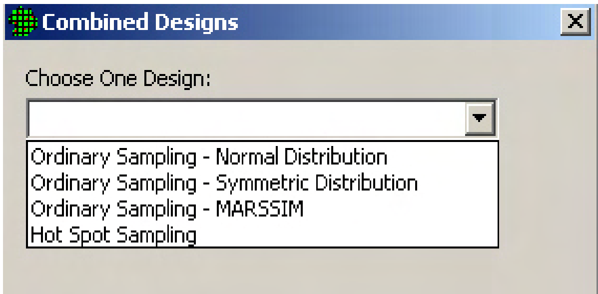


Figure 3.44. Sampling Design Options in VSP for Design 1: Compare Average to a Threshold

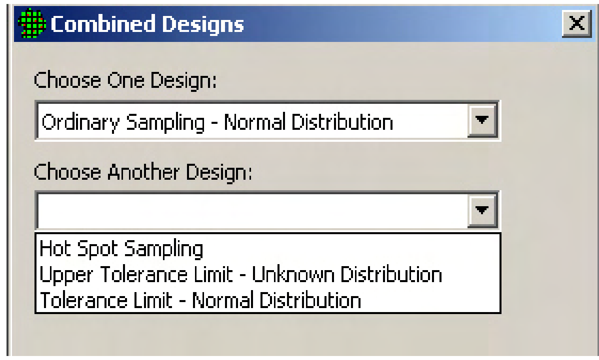


Figure 3.45. Sampling Design Options in VSP for Design 2: Compare Individual Measurements to a Threshold

to a Threshold.

The Hot Spot design is included in the options for both Design 1 and Design 2 to allow the user to choose the combined goals of detecting Hot Spots and Compare Individual Measurements to Threshold. For the Combined Designs Dialog to work properly, the Dialog Boxes for Design 1 and Design 2 must be open. You have to close the Combined Designs Dialog before you can close either of the two individual Design Dialogs.

4.0 Assessment of Sampling Plans

VSP provides multiple displays for allowing you to assess the sampling plan that has been designed/ selected. VSP calls the displays **Views.** You can view a representation of the sampling locations on the map entered into VSP, view a graph of the performance of the design, look at a report that summarizes the key components of the design (such as number of samples, size of sampling area, cost, probabilities associated with the problem, assumptions, and technical justification), or see a listing of the coordinates of each sampling location. This section describes each of these views and discusses how you can use the views to assess the VSP sampling plan.

There are two ways to select/change views:

- Press one of the display buttons in the middle of the tool bar **(MAP VIEW, GRAPH VIEW, REPORT VIEW, COORDINATE VIEW, 3D VIEW). If you are working with rooms, the ROOM VIEW may also be used.**

- From the main menu select **View** > **Map** (or Graph, Report, Coordinate, Room, 3D)

4.1 Display of Sampling Design on the Map: MAP VIEW button or View > Map

In Section 2.2, we described how to set up a **Map.** In Section 2.3, we described how to set up a **Sample Area.** In Section 3.1, we described how to select a **Type of Sampling Plan.** In this section, we find out how to view the results of the sampling design we have just developed and displayed on the map.

In Figure 4.1, we see the display of a simple triangle we drew as our map and selected the entire triangle as our Sample Area. This is available in the file GridSize.vsp, which is included with the VSP program.

We then selected from the main menu **Sampling Goals > Locating a Hot Spot > Assume no false negative errors.** We selected the Probability of Hit to be **90%** and selected a **Square** grid. We entered **4.0** feet for the **Length of Semi-Major Axis** and indicated that we wanted to detect a circular hot spot by selecting a **Shape** of **1.0.** We press **Apply,** and when we return to the map (**View** > **Map**) we see the **22** samples VSP calculated as required to meet the sampling goal displayed. Each time we press **Apply,** we refresh the map display with a new set of random-start sampling locations.

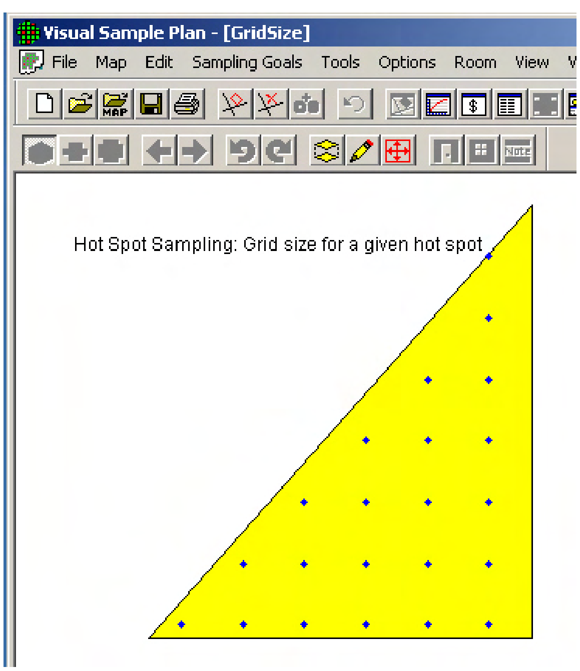


Figure 4.1. Display of Sampling Locations on Map

4.2 Display of Cost of Design

In Section 5.4, we describe how to enter costs. For most sampling designs, Total Cost (per unit plus fixed costs) is tallied and displayed on the same screen where we enter the per-unit costs—under the **Costs** tab on the dialog box used for entering design parameters. Cost information is also usually available in the Report View (**View** > **Report).** Reports are discussed in detail in Section 4.4.

4.3 Display of Performance of Design: GRAPH VIEW button or View > Graph

VSP provides a display of the Performance of the Design for all of the sampling plans that result from sampling goals where a quantitative decision criterion is supplied. For some sampling goals, such as "Estimate the Mean", "Estimate the Proportion", "Assess Degree of Confidence in UXO Presence", "Non-statistical sampling approach", "Combine Average and Individual Measurement Criteria, or "Detect a Trend", where the only criterion the plan must meet is to minimize the variance of the estimate, minimize cost of the estimate, or to calculate a probability, there is little to graph in terms of the performance of the design. For such sampling goals, selecting **View** > **Graph** brings up a blank graph titled "**No Graph**". For some designs, such as "Detect a Trend", the Graph view will display a graph of actual data after it is entered into the Data Analysis page of the design dialog.

For the sampling goals that *do* specify decision error rates or have confidence bounds on the estimates, VSP provides a graph of the performance of the sampling design that has just been created. Each sampling goal, or problem type, has a performance display tailored to it. Each graph tries to show the relationship between some parameter of the sampling design and how effective that design is at achieving the decision criteria. Once a **Sampling Goal** has been selected, the **DQO inputs are** entered on the dialog box input screen, and the **Apply** button is pressed to apply the design to the Sample Area, the display of the performance can be seen by pressing the **GRAPH VIEW** button on the tool bar or selecting **View** > **Graph** from VSP's main menu.

The following sections describe the major displays available for various types of problems. Displays not described are variants of those presented. Some of the graphs associated with unique sampling designs, such as Sequential Sampling, have been described in earlier sections, e.g., Graph View of Sequential Sampling (Figure 3.8), found in Chapter 3. Graphs for **Sampling Goals** > **Find UXO Target** Areas are discussed in Chapter 7.

4.3.1 Performance of Design for Sampling Goal: Compare Average to a Fixed Threshold

The display for the goal of comparing an average to a fixed threshold (i.e., the Action Level) is a graph of the probability of deciding the true mean of the sample area is greater than or equal to the Action Level on the vertical (y) axis as opposed to a range of possible true mean values on the horizontal (x) axis. Figure 4.2 is the Decision Performance Goal Diagram (DPGD) described in EPA's QA/G-4 guidance (EPA 2000a, pp. 6-7 – 6-11). The document can be downloaded from EPA at: http://www.epa.gov/quality/qa_docs.html. Notice how the graph changes as we alternate the null hypothesis between "Assume Site Dirty" to "Assume Site Clean."

The solid vertical red line is positioned at a true mean value of **10,** which corresponds to the Action Level. The area in gray hash marks is the gray region shown here from 8 to 10 and input as a delta (width) of **2.** The two dashed blue lines that extend from the y-axis to the x-axis mark the two types of decision error rates, alpha, set here at **5%,** and beta, set here at **10%.** Recall that Alpha is the probability of rejecting the null hypothesis when it is true (called a false rejection decision error), and beta is the probability of accepting the null hypothesis when it is false (called a false acceptance decision error). The error rates along with

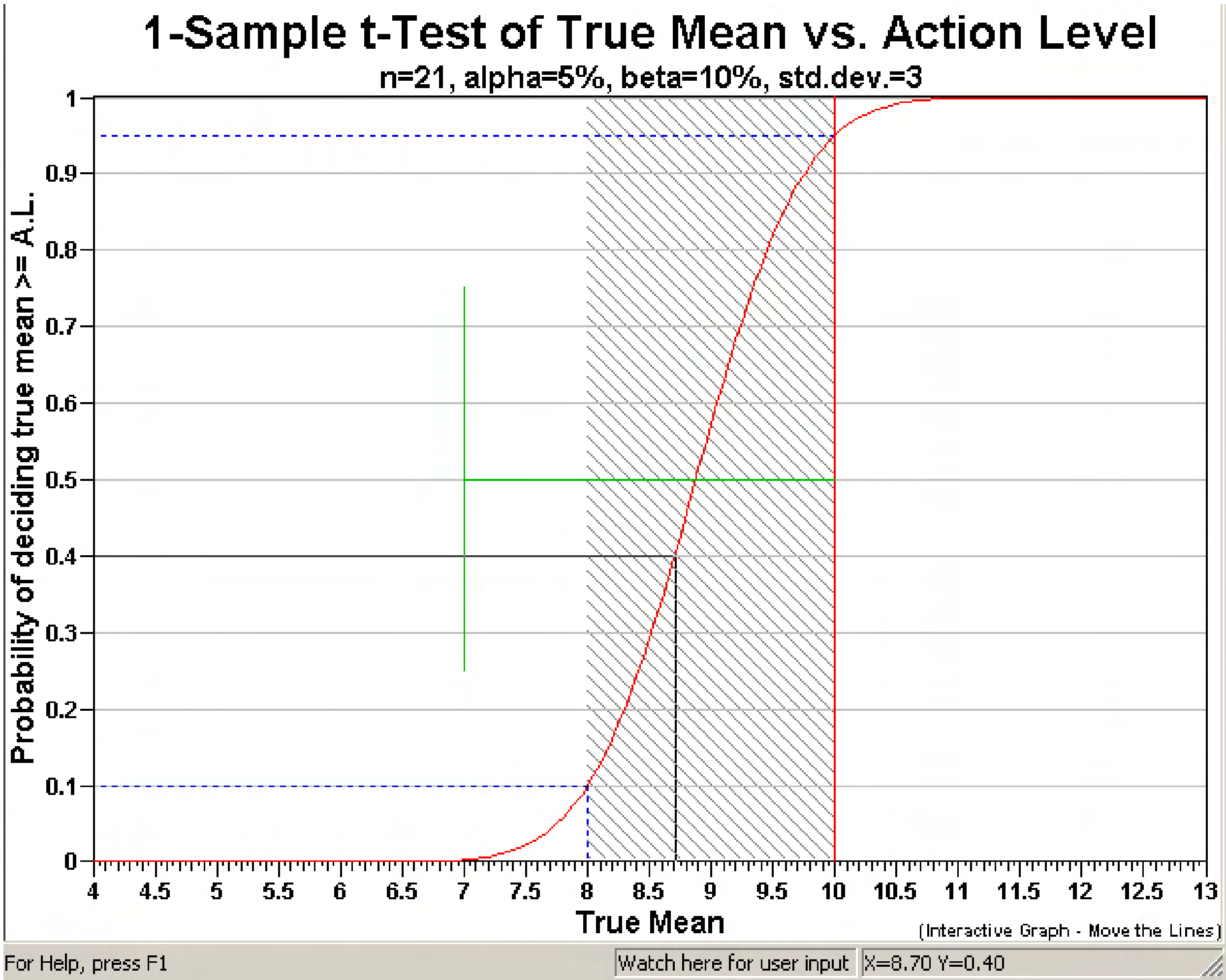


Figure 4.2. Decision Performance Goal Diagram for *Null Hypothesis: True Mean >=Action Level* for Comparing Mean vs. Action Level

the user-supplied standard deviation of **3** and the VSP-calculated sample size **n=21** are shown on the second row of the title. We also see in the title that we are using the sample size formula for the one sample t-test.

The green vertical line marks off one standard deviation (3) from the action level. This mark allows the user to visually compare the width of the gray region to how variable, on average, we expect individual observations to be about the mean (definition of standard deviation). The sliding black lines (cross hairs) that move on the graph when the mouse is moved are provided to facilitate reading the x, y values off the graph. This cross-hair feature can be turned off or on by choosing **Options > Graph > Display Cross Hairs.**

Most of the parameters displayed on the DPGD can be changed interactively by moving the lines on the graph, rather than having to change the values in the input dialog box. Table 4.1 describes the interactive features.

As you change these parameters, you can see the new value of the parameter on the bottom status bar after "watch here for user input." You will notice that changing these values on the graph also changes

Table 4.1. Interactive Graph Features

To Change	Do the Following
Alpha	Drag the horizontal blue dashed line up or down
Beta	Drag the horizontal blue dashed line up or down
Delta (and LBGR, or UBGR)	Drag the vertical edge of the shaded gray area to the left or right
Standard Deviation	Drag the vertical section of the green line left or right
Action Level	Drag the vertical red line left or right
Null Hypothesis	Click on the y-axis title

these values on the other displays: the sampling design is modified in the report view, new samples are placed on the map view, and updated sample location information is list in the coordinate view.

Right-clicking anywhere in the graph brings up a pop-up menu. The options in the menu are described in Table 4.2. This pop-up menu provides quick access to the menu choices available from the main menu under **Options** > **Graph**. One of the options is to view the complement of the Decision Performance Goal Diagram, which is referred to as the "Operating Characteristic" Curve. We select this option and the OC curve is shown in Figure 4.3. Note that the Y-axis is now labeled, "Probability of making the correct decision".

Table 4.2. Graph Options Menu Commands

Display Cost	Display cost on any graph axis that would otherwise display the number of samples.
Display Cross Hairs	Display an interactive cross-hair that allows the user to see the X and Y values for any point on the graph
Display Current Value	Displays a cross-hair that corresponds to the current X or Y value produced by the current sampling design.
Probability of Correct Decision	Displays the probability of a correct decision in place of a decision performance goal diagram
MQO Method Comparison	Displays a bar graph that shows the relative costs of MQO sampling design alternatives.
Barnard's Log Likelihood Ratio	Displays a plot of Barnard's Log Likelihood Ratio (which is the test statistic used in Barnard's sequential t-Test)
Plot Linear Regression	Displays the linear regression plot (available for collaborative sampling designs).
Pick UXO Graph	Allows user to choose which saved power curve they wish to display in the report view.

When the null hypothesis is stated as **H_0: True Mean ≥ Action Level** (Site is Dirty), the gray region is on the left side of the Action Level. However, when the null hypothesis is stated as **H_0: True Mean ≤ Action Level** (Site is Clean), the gray region is on the right side of the Action Level. In practical terms, when we assume a site is dirty, the majority of the decision errors will occur for clean sites with true means just below the Action Level. On the other hand, when we assume a site is clean, the majority of decision errors will occur for dirty sites with true means just above the Action Level.

The DPGD graph in Figure 4.2 is telling us that for the "Site is Dirty" null hypothesis,

- Very clean sites will almost always result in sets of random sampling data that lead to the decision "Site is Clean."

- Very dirty sites will almost always result in sets of random sampling data that lead to the decision "Site is Dirty."

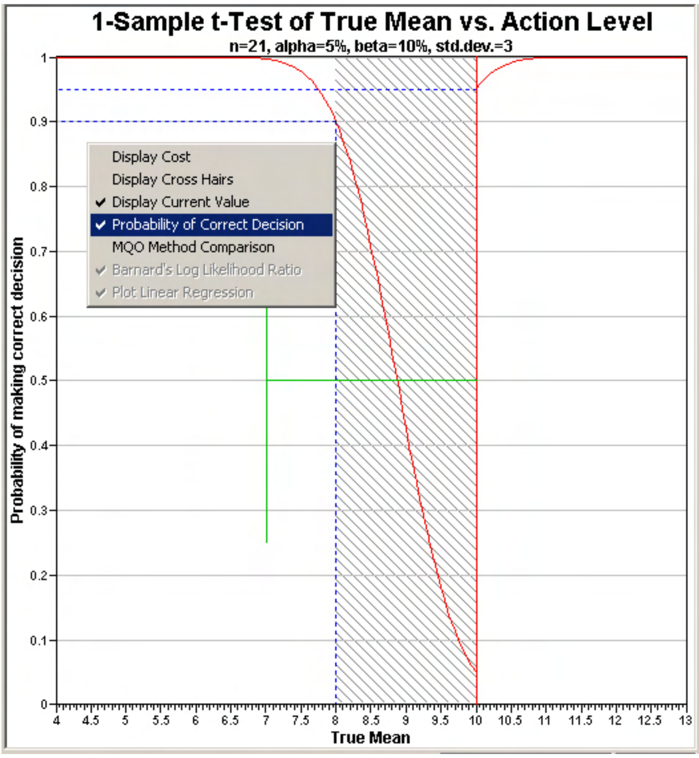


Figure 4.3. Graph of Probability of Making Correct Decision

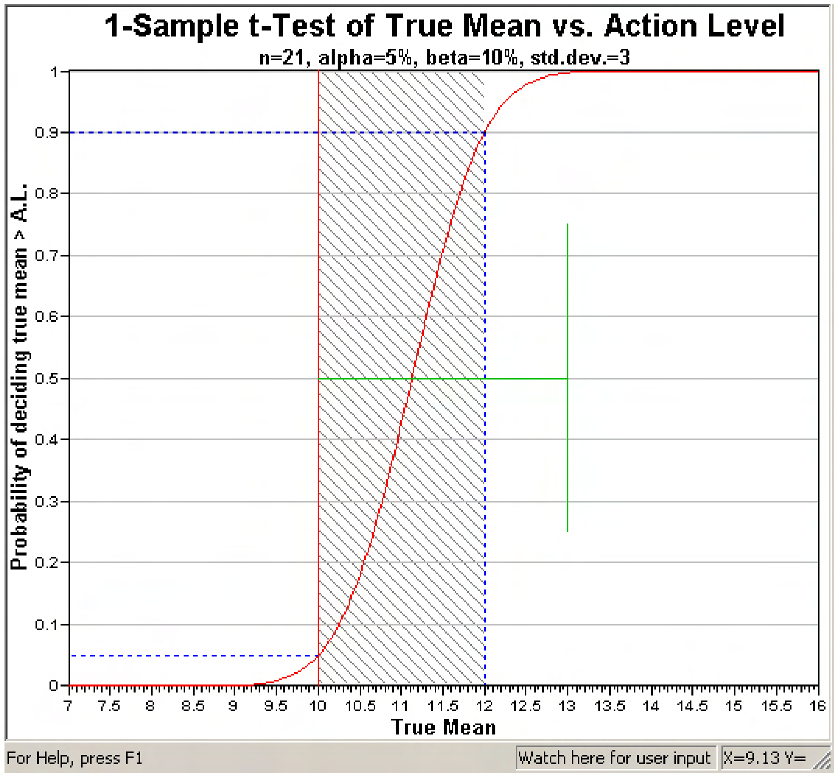


Figure 4.4. Decision Performance Goal Diagram for *Null Hypothesis: True Mean <= Action Level* for Comparing Mean vs. Action Level

What we may not know intuitively is how our choice of the null hypothesis affects decisions near the Action Level. The graph in Figure 4.2 also is telling us

- Clean sites with true means just *below* the Action Level will lead to mostly *incorrect* decisions.
- Dirty sites with true means just *above* the Action Level will lead to mostly *correct* decisions.

However, when we reverse the null hypothesis and state it as **H_0: True Mean ≤ Action Level, i.e.,** assume "Site is Clean," we see in Figure 4.3 that the gray region where the majority of decision errors occur shifts to the right side of the Action Level. Sites that are dirty now lead to the majority of decision errors. Also note that alpha is now defined for values less than the action level, while beta is defined for values above the upper bound of the gray region.

You should carefully study EPA's QA/G-4 guidance document (EPA 2000a, especially pp. 6-1 to 7-6) to better understand how to use VSP to balance the choice of null hypothesis, decision error rates, width of the gray region, total sampling costs, and costs of incorrect decisions.

4.3.2 Performance of Design for Sampling Goal: Construct Confidence Interval on the Mean

The display for assessing a confidence interval for a mean differs somewhat from that for comparing an average to a threshold because this is an estimation problem, not a testing problem. As such, there is only one type of decision error rate, alpha. Shown in Figure 4.5 is the Performance Design for a problem where the user specified the width of the confidence interval as **1.0,** the standard deviation as **3,** and a desired

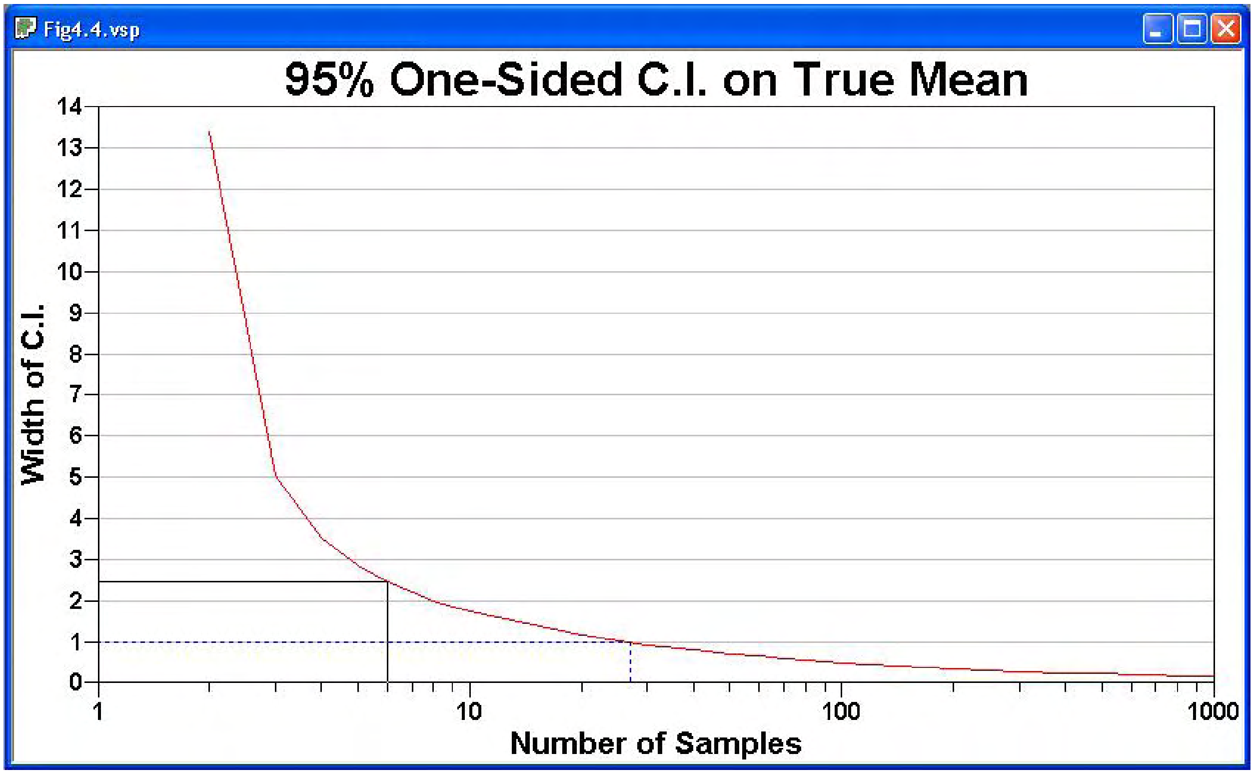


Figure 4.5. Decision Performance Graph for One-Sided 95% Confidence Interval

95% one-sided confidence interval on the mean. We are using a one-sided confidence interval (vs. a two-sided) because we are concerned only about values that exceed the upper bound of the confidence interval, not values both above the upper bound and below the lower bound. This is consistent with problems in which the mean to be estimated is average contamination, so we are not concerned about values below the lower bound of the confidence interval.

VSP calculated that a sample size of **26** was required. The performance graph is a plot of possible confidence interval widths vs. number of samples for the problem specified. The dashed blue line terminates at the y-axis at a confidence interval width of 1.0, as specified by the user, and at the x-axis at the recommended minimum sample size of 26.

The solid black line is a locating aid you can slide up and down the graph to easily read the trade-offs between increased width of the confidence interval and increased number of samples. In Figure 4.5, the x-axis value (number of samples) and the y-axis value (width of confidence interval) for the current solid black line can be seen in the status bar as X = 2.72 and Y = 5.96.

4.3.3 Performance of Design for Sampling Goal: Comparing a Proportion to a Fixed Threshold

The sampling design assessment display for comparing a proportion to a fixed threshold is a graph of the DPGD for the DQO inputs supplied. **Note:** If the appropriate statistical test is used, the test is designed to achieve the level of significance, or alpha. It is beta and the power of the test (1-beta) that are affected by sample size.

For this sampling goal, there is no clear distinction between "Site Dirty" and "Site Clean," depending on how the null hypothesis is formulated. If the proportion we are talking about is the proportion of 1-acre lots in a building development that have trees, then exceeding a threshold would be a "good thing." However, if the proportion is the proportion of acres that have contamination greater than 10 pCi, then exceeding the threshold would be a "bad thing." Alpha and beta are still defined as false acceptance and false rejection rates, but the user must formulate the hypotheses and select limits on the error rates consistent with the goals of the project and which type of error is most important to control.

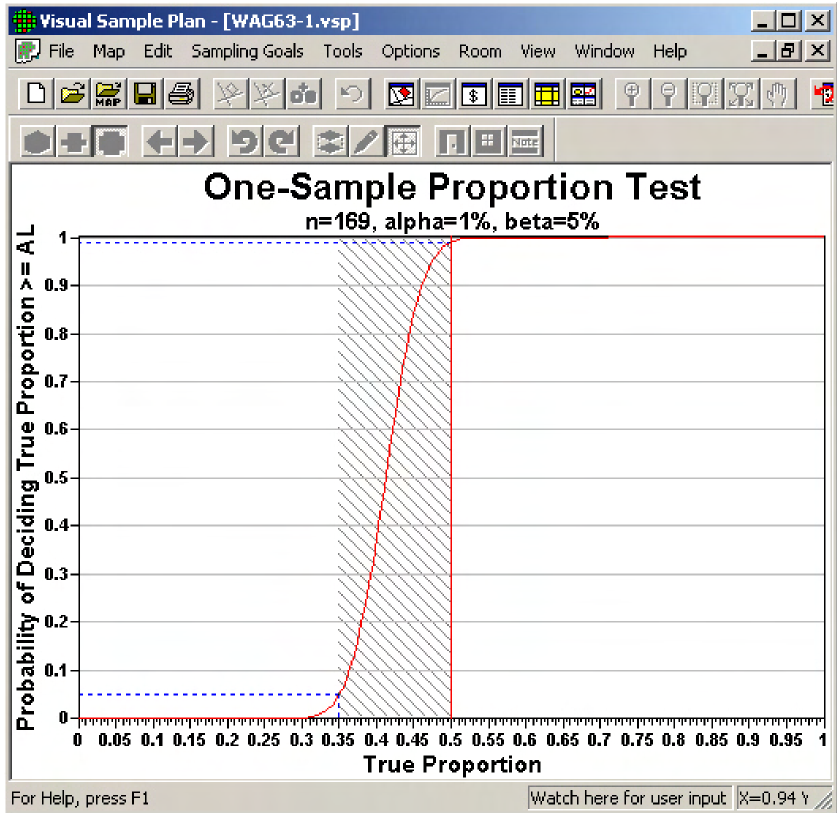


Figure 4.6. Decision Performance Goal Diagram for Comparing a Proportion to a Fixed Threshold

In the example in Figure 4.6, the null hypothesis was set to **True Proportion ≥ Given Proportion.** As such, beta is the probability of deciding the proportion exceeds the threshold when the true proportion is equal to or less than the lower bound of the gray region. For this problem, we set alpha to **1%** and beta to **5%,** and the lower bound of the gray region to **0.35 (i.e.,** width of gray region = 0.15). The proportion we want to test against (Action Level) is **0.5**. This Action Level is the default for VSP because it is the most conservative. That is, the most number of samples are needed to differentiate a proportion from 0.5 (vs. differentiate a proportion from any other percentage).

4.3.4 Performance of Design for Sampling Goal: Compare Average to Reference Average

The sampling design performance display for comparing the true means of two populations when the **assumption of normality can be made** is a graph of the probability of deciding if the difference of true means is greater than or equal to the specified difference (Action Level) vs. various differences of true means. This graph is similar to the Decision Performance Goal Diagram discussed in Section 4.3.1, but this time we are dealing with two populations, and the x-axis is a range of possible *differences* between the two population means.

The graph shown in Figure 4.7 is for **H_0: Difference of True Means ≥ Action Level.** We revert back to the notion that this null hypothesis implies a " Dirty Site" condition. If the action level is a positive number, we would classify the site as greater than background or “Dirty.” For this problem, the specified difference of the two means (Action Level) is **5,** the width of the gray region is **2,** alpha = **5%,** beta = **10%,** and the estimated common standard deviation = **3.**

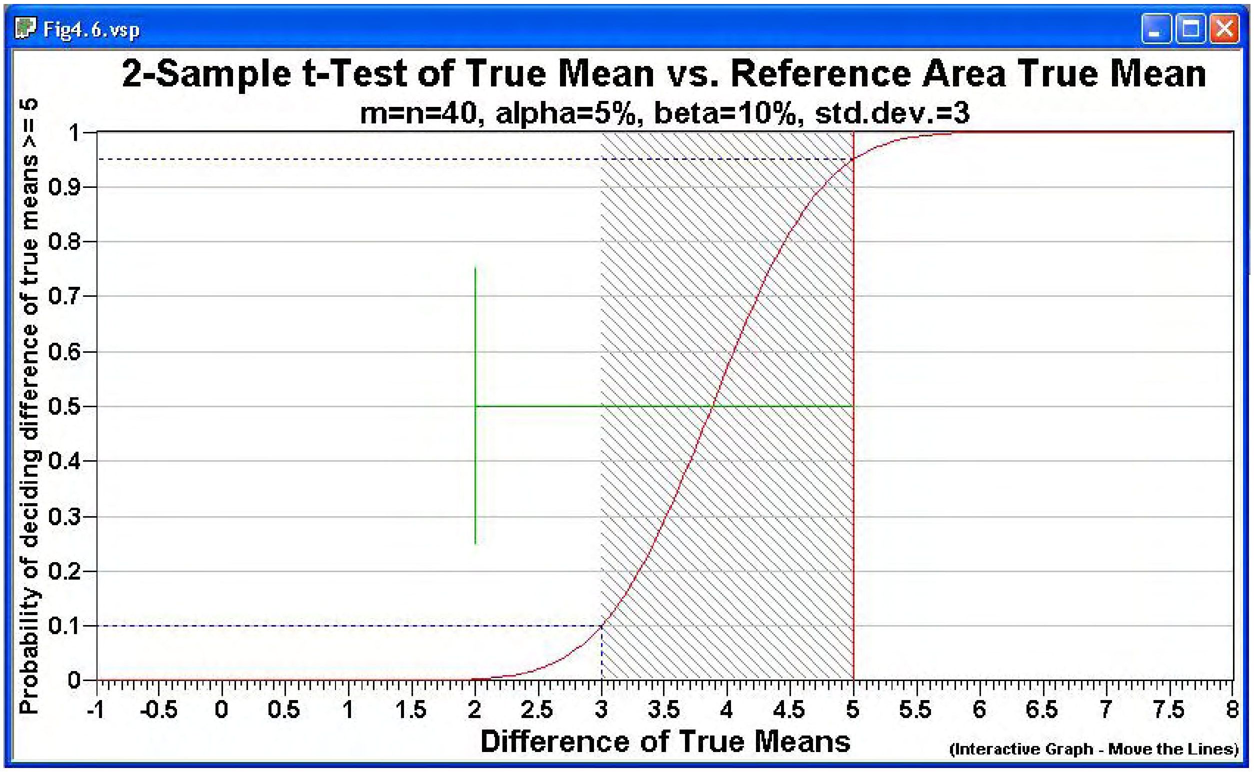


Figure 4.7. Decision Performance Goal Diagram for Comparing a Sample Area Mean to a Reference Area Mean

Note: The standard deviation is the average expected difference between the individual units in a population and the overall mean for that population. It is assumed that both populations (Sample Area and Reference Area) have the same standard deviation. The graph is labeled “2-Sample t-Test” because it is assumed that the two-sample t-test will be used as the statistical test.

The title of Figure 4.7 shows that we need to take 40 samples both in the Sample Area and 40 samples in the Reference Area. The probabilities of deciding the Sample Area is 5 or more units (pCi/g, ppm, etc.) above the Reference area are plotted against the true differences in means. The standard deviation is shown as the green line at a distance of 3 from the Action Level.

When the assumptions of **data are not required to be normally distributed** is made, we can see from the pull-down menu lists under Sampling Goals that two non-parametric statistical tests are proposed – the Wilcoxon rank sum test and the MARSSIM WRS (Wilcoxon rank sum) test.

The Decision Performance Goal Diagrams for the two nonparametric tests are similar to the DPGD for the parametric two-sample t-test. In Figure 4.8, we see the DPGD for the MARSSIM WRS test using the same inputs as the problem in Figure 4.7. The difference of true means or medians is plotted on the x-axis, and the probability of deciding the difference is equal to or greater than the action level of 5 is shown on the y-axis. For the MARSSIM formulation of the WRS test, the action level is the DCGLw. The lower bound of the gray region is the difference in means or medians where we want to limit the beta error.

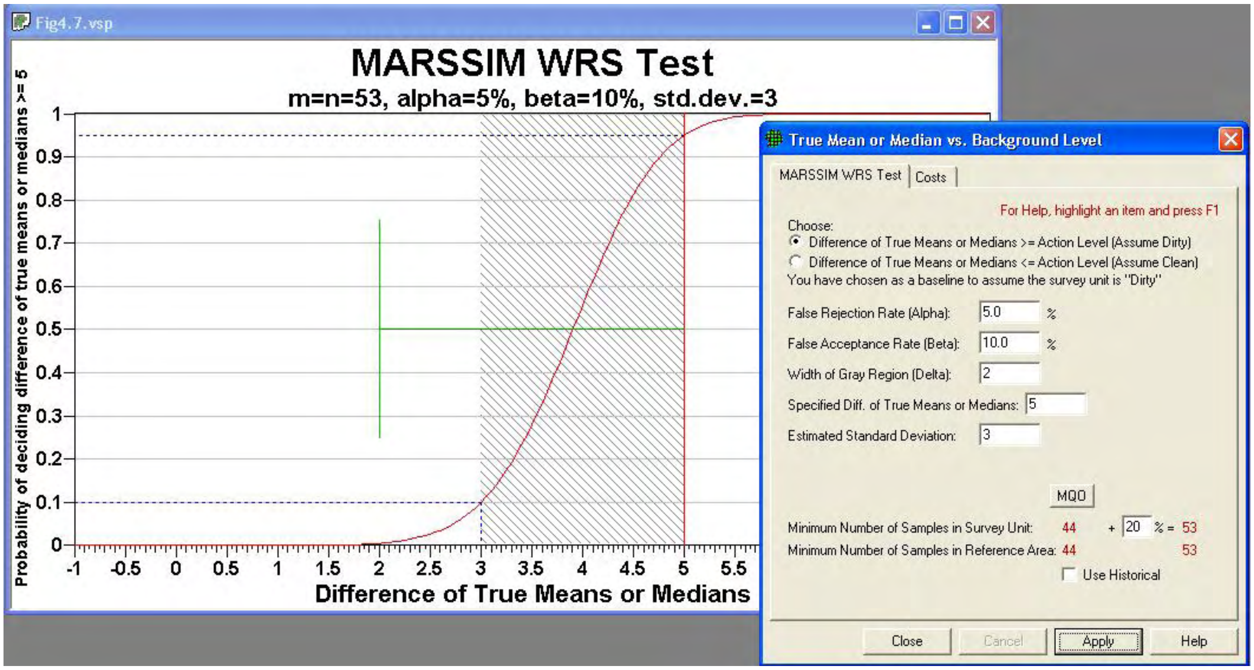


Figure 4.8. Decision Performance Graph for Comparing a Sample Area Mean to a Reference Area Mean (Nonparametric Version, MARSSIM WRS)

Shown in Figure 4.8, the input dialog for the MARSSIM WRS test allows the user to supply a percent overage to apply to the sample size calculation. MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and for uncertainty in the calculated values of Sample Size, n. With the extra 20%, the sample size now becomes 53 samples required in both the Sample Area (i.e., Survey Unit or Study Area) and Reference Area.

4.3.5 Performance of Design for Sampling Goal for Hot Spot Problem

The Decision Performance Goal Diagram for the hot spot problem is a graph of number of samples on the x-axis and the probability of hitting a hot spot of a specified size on the y-axis. The heading of the performance graph lists the size of the hot spot and the size of the sample area. The trade-off displayed is that by increasing the number of samples (i.e., a tighter grid spacing and hence the higher cost), and/or changing the grid type (say from square to triangular), there is a higher probability of hitting the hot spot with one of the nodes on the grid. This is almost a straight-line relationship until we get into larger sample sizes, and then the efficiency is diminished.

Returning to the problem we laid out in Section 4.1, for the sampling goal of **Sampling Goals > Locating a Hot Spot > Assume no false negative errors > Systematic Grid Sampling,** the graph is shown in Figure 4.9. This graph is for the 1130.84 ft^2 Sample Area shown in Figure 4.1 and for finding a **4-ft** round hot spot. The graph shows the desired input of **90%** probability of hitting the circular hot spot of radius 4 ft. and the **22** samples required to achieve this. The DPGD for this problem is a graph of the % probability of a hit on the Y axis vs. the number of samples using a square grid on the X axis. The user can move the cursor along the curve to read off alternative combinations of probability of a hit for different samples sizes (i.e., grid size).

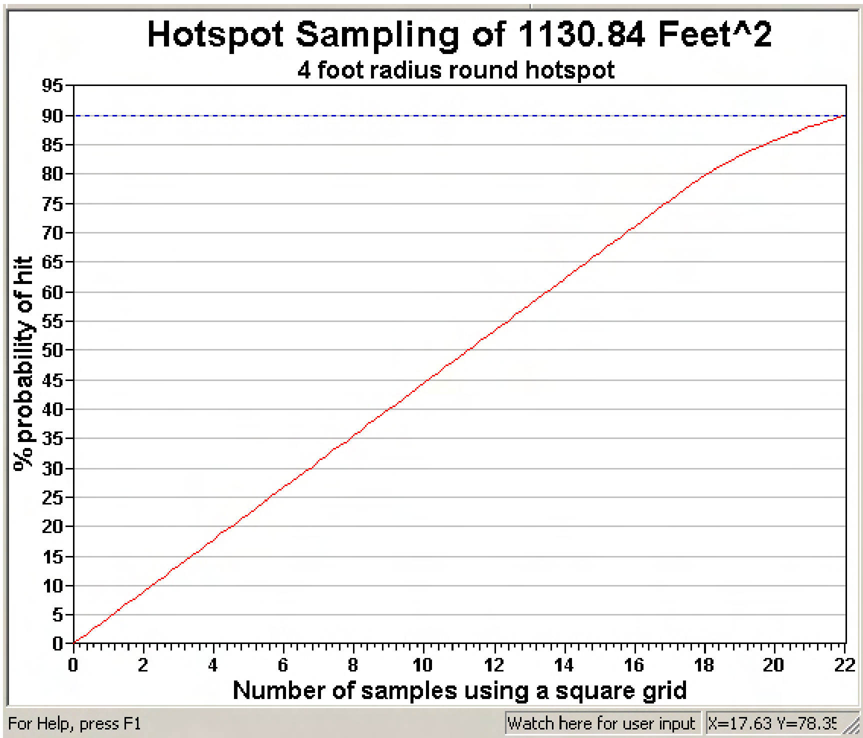


Figure 4.9. Probability of Hitting a Hot Spot vs. Number of Samples

VSP may place a slightly different number of sampling points (nodes) on a map than the exact number calculated. The difference between the calculated number of sample and the number of samples placed on the map is 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas. Repeatedly pressing the **Apply** button from the dialog box will select a different random starting point for the grid and may change the number of samples that will fit in the sample area.

The probability of hit is a geometric relationship between the grid spacing and the hot spot size and shape. The probability of hit is *not* a function of number of samples. On the graph, however, grid spacing is translated to the number of samples on a *theoretical* sampling area. The number of theoretical samples is shown on the graph because it is a more meaningful metric for the user than grid spacing. The dashed blue line on the performance curve shows the number of samples that fit on the *actual* sample area given the starting point. The report also lists the actual number of samples placed on the map.

Important note: Regardless of where the dashed blue line occurs on the graph, the probability of a hit for *your* sampling design is the one you specified and is shown on the sampling goal dialog. This is true because the probability of a hit is a geometric relationship between the grid spacing and the hot spot size and shape.

Deselecting the Random Start on the dialog box removes the random assignment of the grid and keeps the grid fixed with each repeated hit of the Apply button, keeping the same sample size.

4.3.6 Performance of Design for Sampling Goal of Compare Proportion to a Reference Proportion

The graph for displaying the performance of the design for comparing a proportion to a reference proportion is similar to the comparison of two population means (see Figure 4.7). As such, the difference between the two true proportions is shown on the x-axis, and the probability of deciding that the difference between the two true proportions is greater than a specified difference (i.e., the Action Level) is shown on the y-axis. The two proportions being compared could be, say, the proportion of children with elevated blood lead in one area compared to the proportion in another area, or it could be the percentage of 1-m squares within an acre that have contamination greater than 1 ppm of dioxin. The comparison might be to compare the amount of contamination (stated as a percentage remaining at a site after it has been remediated) to a background or reference area. Using the naming convention in EPA (2000b, pp. 3-27 – 3-31), the site (also called the survey unit, Sample Area) is Area 1, and the reference or background area is Area 2. The document can be downloaded from the EPA site: http://www.epa.gov/quality.qa_docs.html.

In Figure 4.10, we see the inputs from the dialog box along with the Decision Performance Goal Diagram. The example has as the null hypothesis "no difference between site and background," or Ho: $P1 - P2 \leq 0$. The two estimated proportions are required to calculate the standard deviation for the pooled proportion used in the sample size formula. With this formulation, the specified difference (Action Level) is 0, and the false acceptance error rate (beta = 5%) is set at the difference of $P1 - P2 = 0.10$. Thus, 0.10 is the upper bound of the gray region, which VSP requires to be greater than the Action Level. When the null hypothesis is changed to Difference of Proportions ≥ Specified Difference, the lower bound of the gray region is less than the action level.

The graph in Figure 4.10, labeled the Two-Sample Proportion Test, lists the inputs of alpha, beta, and the two estimated proportions in the heading line. The S-shaped curve shows that for larger differences in the true proportions, the probability of correctly deciding the difference exceeds the Action Level increases. This is intuitive because the greater the difference between two populations, the easier it is to correctly distinguish that difference from a fixed threshold (Action Level).

4.3.7 Performance of Design for Sampling Goal of Establish Boundary of Contamination

In Figure 4.11 we see the performance of the sampling design defined by the inputs shown in Figure 3.36 applied to the Sample Area of the large "oval" in the Millsite.dxf file (see Map View in Figure 3.38). This problem is for the **Enclosing Boundary**. In order to have a **95%** confidence of finding a hot spot of

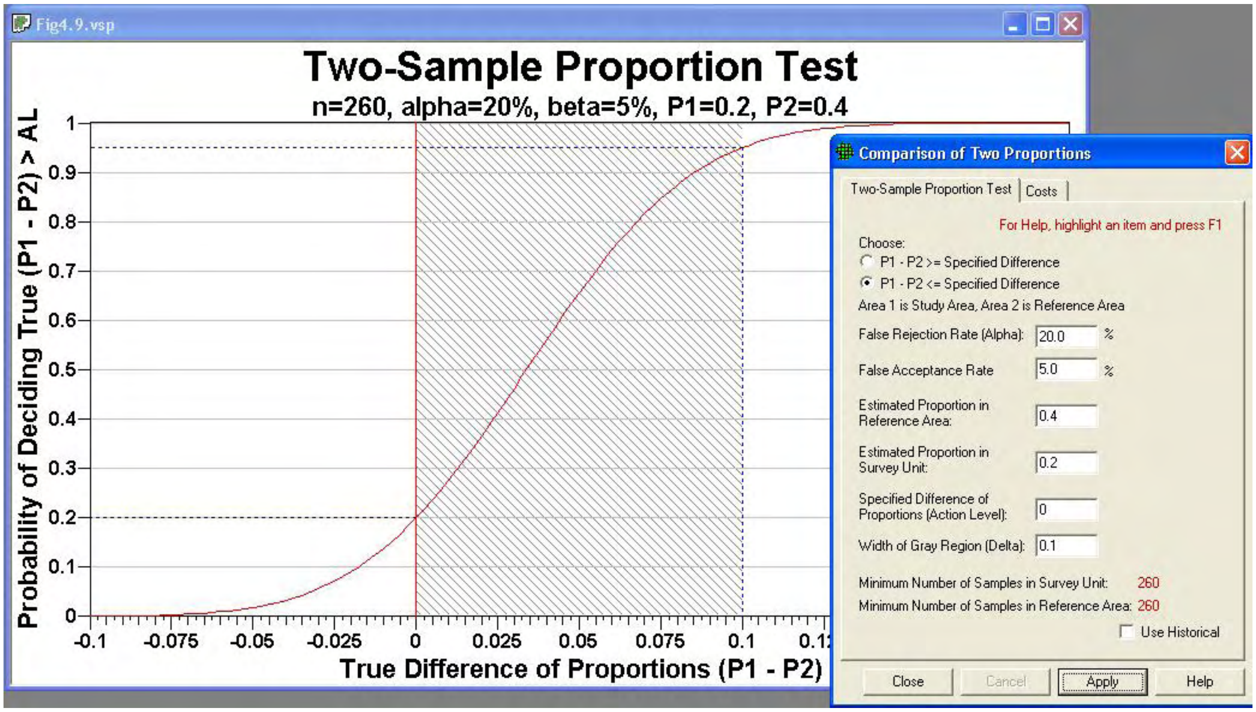


Figure 4.10. Decision Performance Goal Diagram for Comparing a Sample Area Proportion to a Reference Area Proportion. Input dialog box for design shown as insert.

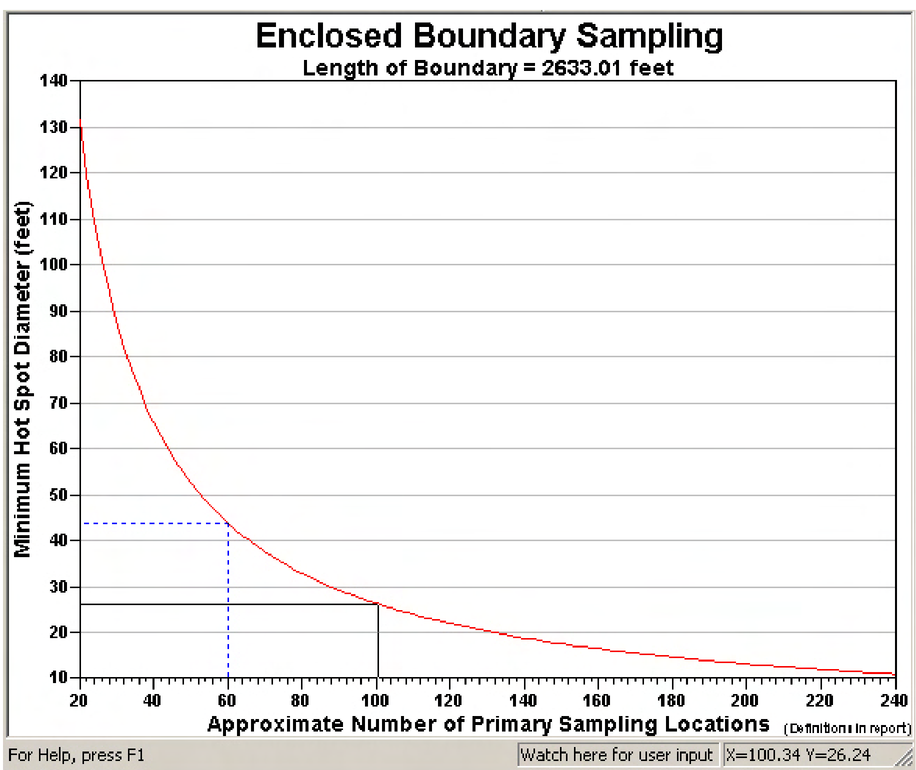


Figure 4.11. Curve of Trade-off Between Primary Sampling Locations and Size of Hot Spot that can be Detected

diameter of **45 ft**, we need **12** segments. This dictates we need **60** Primary Sampling Locations (12 x 5 = 60). The relationship between diameter of hot spot and number of primary sampling locations is shown in the dashed blue line positioned on the performance curve shown in Figure 4.11. The dashed line shows the current number of Primary Sampling Locations for this design (n = 60), which may differ from the optimum number because of rounding and bump-out effects. We can see from the cross hairs positioned on the performance curve (right-click on graph, and toggle the **Display Cross Hairs** to "on"), that if we expand our Primary Sampling Locations to 100, we could detect a hotspot of diameter 27 ft. with the sample level of 95% confidence.

The sample type of graph is produced for the **Open Boundary** Sampling Problem.

4.4 Display of the Report

One of the most valuable outputs from VSP is the Report that is generated for each application of a Sampling Design to a Sample Area. The Report View for a sampling design is available by either selecting the **REPORT VIEW** button on the toolbar, or by selecting **View > Report** from the main menu. The only Sampling Goals that do not produce Reports are **Non-statistical sampling approaches** and **Comparisons of two proportions.**

The Report provides the VSP user with a complete documentation of the sampling design selected. The report includes:

- statement of sampling objective,
- the assumptions of the design,
- sample size formula,
- inputs provided by the user,
- summary of VSP outputs including sample size and costs,
- list of samples with their coordinates and labels,
- map with sample locations identified,
- Performance Goal Diagram,
- Peer-reviewed technical references for designs and formulas,
- technical discussion of the statistical theory supporting the sampling design and sample size formula.

The reports are suitable for incorporation into a quality assurance project plan or a sampling and analysis plan. The report for some of the sampling designs include:

- recommended data analysis activities for how data should be used in the appropriate statistical test to make a decision,

- insight into options presented in the Input Dialog Box,

- sensitivity tables showing how sample number changes as input parameters change, and

- extended statistical discussions and support equations.

Some of the output from VSP, for some designs, is viewable only within the report. VSP users can use the information in the **Report** as an additional source of **Help**.

A few selections from the report for the selection **Sampling Goals > Compare Average to a fixed threshold > Can assume data will be normally distributed > Ordinary Sampling** are shown in Figure 4.12. Each time VSP calculates a new sample size, changes VSP input, or adds points to an existing design, the report is updated automatically. The complete report can be copied to the clipboard for pasting into a word

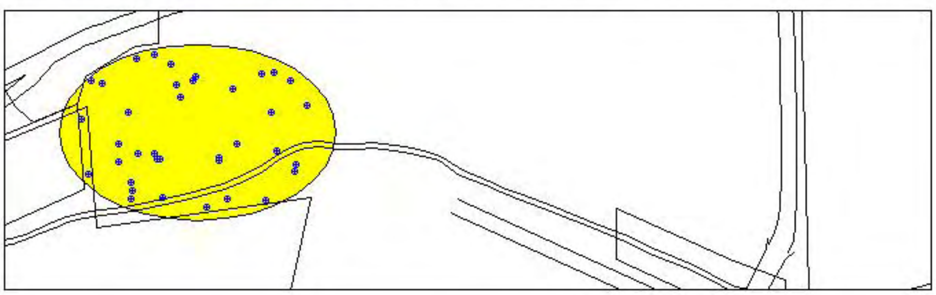
Random sampling locations for comparing a mean with a fixed threshold (parametric)

Summary
This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean to a fixed threshold
Type of Sampling Design	Parametric
Sample Placement (Location) in the Field	Simple random sampling
Working (Null) Hypothesis	The mean value at the site exceeds the threshold
Formula for calculating number of sampling locations	Student's t-test
Calculated total number of samples	37
Number of samples on map [a]	37
Number of selected sample areas [b]	1
Specified sampling area [c]	509779.78 ft^2
Total cost of sampling [d]	$19500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.



Area: Area 1					
X Coord	Y Coord	Label	Value	Type	Historical
2265128.4318	10285981.0061		0	Random	
2265305.4734	10285630.1118		0	Random	
2265161.3618	10285860.6159		0	Random	
2265563.9628	10285920.1073		0	Random	

Figure 4.12. Report View of the Sampling Goal: Compare Average to a Fixed Threshold, Normality Assumed, Ordinary Sampling

processing application like Microsoft Word by selecting **Edit > Copy** from the main menu when the report view is active. The text and graphics are copied using rich text format (RTF) to preserve formatting. The user opens Microsoft Word, selects **Paste,** and the entire report is copied into a Word document.

The sensitivity table in the **Report View** allows the user to do "what-if" scenarios with VSP input and output. For the sampling problem shown in Figure 4.12, the sensitivity table shows how sample size changes with changes in the standard deviation and the two decision error rates, alpha and beta. Different sampling goals and sets of assumptions have different variables and parameters in their sensitivity table. The user can change the variables and range of values shown in the sensitivity table by right-clicking anywhere in the report. A dialog box, as shown in Figure 4.13a, is displayed to allow the user to choose which of up to four variables will be displayed in the sensitivity table, along with each variable's starting and ending value, and the step-size. Shown in red are the values the variables will take.

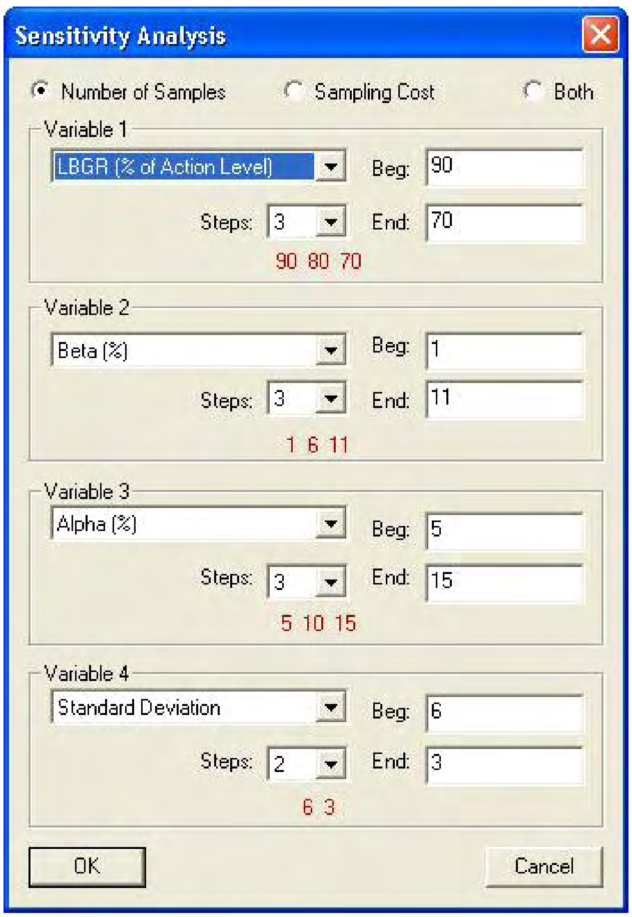


Figure 4.13a. Dialog Box for Changing Variables Displayed, and Range for Variables Shown, in Sensitivity Table in Report View. Shown here is input dialog for sampling goal of compare average to threshold, normality assumed (parametric), ordinary sampling.

Figure 4.13b shows the sensitivity table that will be included in the Report (**View** > **Report**). Displayed in the table can be the number or samples, cost, or both. Certain sampling designs have the option to show parameters other than cost.

The Report changes based on the Sampling Goal selected. Figures 4.14 and 4.15 show portions of the Report for the sampling goal of **Sampling within a Building**. Shown are the two sampling areas: rooms in yellow are Sampling Room 1; rooms in green are Sampling Room 2, which is also the **Current Rom**. In Figure 4.15 we also see the detail on the samples placed within the two rooms, along with their actual and relative coordinates, type of sample, and whether the sample is placed on the floor, ceiling, walls, or windows and doors.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying s, LBGR, β and α and examining the resulting changes in the number of samples. The following table shows the results of this analysis.

Number of Samples								
AL=10		**α=5**		**α=10**		**α=15**	
		s=6	**s=3**	**s=6**	**s=3**	**s=6**	**s=3**
LBGR=90	**β=1**	570	144	470	118	408	103
	β=6	370	94	291	74	243	61
	β=11	299	76	228	58	185	47
LBGR=80	**β=1**	144	37	118	31	103	26
	β=6	94	25	74	19	61	16
	β=11	76	20	58	15	47	13
LBGR=70	**β=1**	65	18	53	14	46	12
	β=6	43	12	34	9	28	8
	β=11	35	10	26	8	22	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling

The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $19500.00, which averages out to a per sample cost of $527.03. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**37 Samples**
Field collection costs		$100.00	$3700.00
Analytical costs	$400.00	$400.00	$14800.00
Sum of Field & Analytical costs		**$500.00**	**$18500.00**
Fixed planning and validation costs			$1000.00
Total cost			**$19500.00**

Figure 13b. Sensitivity Table for Sampling Goal: Compare Average to a Fixed Threshold, Normality Assumed, Ordinary Sampling. Cost information shown in bottom of figure.

VSampl2

Sampling to Compute a Normal Distribution One-Sided Upper Tolerance Limit to Test that a Large Portion of Room Surfaces Does Not Contain Contamination

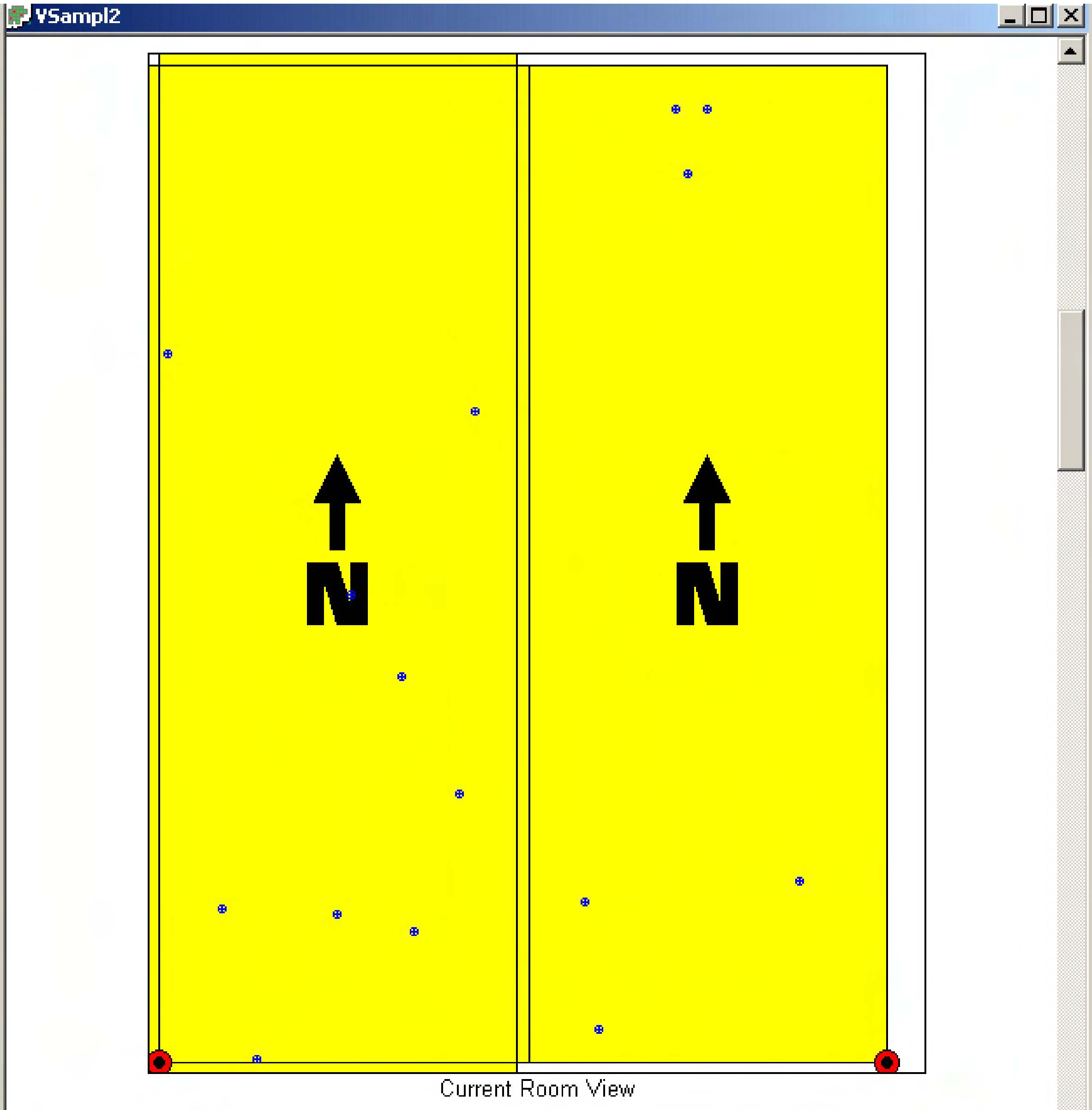
Summary

This report summarizes the sampling design developed by VSP based on inputs provided by the VSP user. The following table summarizes the sampling design developed by VSP. Figures that show the sample placement in the rooms and a table that lists the sample locations are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Use a one-sided upper tolerance limit (UTL) to test if the true P^{th} percentile of a normally distributed population exceeds the action level
Required fraction of population to be less than the action level	0.9 (90%)
Required percent confidence on the decision made using the UTL	95%
Method used to compute the number of samples	Lyles and Kupper (1996) (See equations below)
Sample placement method	Simple random sampling
Calculated total number of samples	47
Number of samples on map [a]	47
Number of selected rooms	2
Total sampling surface area [b]	1025890.88 ft^2
Total cost of sampling [c]	$24500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas (rooms).
[b] This is the total surface area of all selected rooms and other selected sample areas on the map of the site.
[c] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.

Figure 4.14. Report View for Sampling within a Building. Shown are summary information for design and location of samples areas selected within the floor plan.



Area: Room 1									
X Coord	Y Coord	Z Coord	Label	Value	Type	Historical	Surface	LX	LY
2665.3158	2863.4641	0.0000		0	Random		Floor	30.9442	1086.0868
2759.7049	2092.1033	0.0000		0	Random		Floor	125.3333	314.7260
2794.0743	2753.7797	0.0000		0	Random		Floor	159.7027	976.4024
2724.5903	2523.9724	8.0000		0	Random		Ceiling	90.2187	746.5951
2642.5047	1854.2216	8.0000		0	Random		Ceiling	8.1331	76.8443

Figure 4.15. Report View for Sampling within a Building. Shown are current room, and sample information.

4.5 Display of Coordinates

The fourth type of display in VSP is the list of coordinates for each sample point on the map. We can see this display by using the **COORDINATE VIEW** button on the toolbar, or by selecting Main Menu option **View** > **Coordinates.** The x and y coordinates are displayed for each sample point. Also displayed are the sample points label, a value (if entered by the user), the type (e.g., random, systematic, RSS), and a "true/false" indicator of whether or not this sample point is an historical sample (previously taken sample). Coordinates are segregated by Sample Area. These coordinates can be copied and pasted into a spreadsheet or word processing file using Main Menu option **Edit > Copy.** Figure 4.16 is an example of the Coordinates view. The Sampling goal **Sampling Goals > Find UXO Target Areas** has a **Data Entry and Analysis tab** used for exporting coordinates to be edited outside of VSP (see Chapter 7), and the coordinates are not displayed in the COORDINATE VIEW due to these datasets often being large. If searching for target areas, we don't display the coordinates. See Chapter 7 for more information.

Area: Area 1

X Coord	Y Coord	Label	Value	Type	Historical
2265128.4318	10285981.0061	VSP-1	0	Random	
2265305.4734	10285630.1118	VSP-2	0	Random	
2265161.3618	10285860.6159	VSP-3	0	Random	
2265563.9628	10285920.1073	VSP-4	0	Random	
2265578.9547	10285591.6967	VSP-5	0	Random	
2264986.3670	10285519.3750	VSP-6	0	Random	
2265259.0015	10285457.0271	VSP-7	0	Random	
2265149.0585	10285908.0085	VSP-8	0	Random	
2264934.5577	10285689.4339	VSP-9	0	Random	
2264825.5277	10285581.4322	VSP-10	0	Random	
2265206.7974	10285920.6213	VSP-11	0	Random	
2264979.1298	10285547.6926	VSP-12	0	Random	
2265004.4190	10285655.0953	VSP-13	0	Random	
2265492.7605	10285807.0948	VSP-14	0	Random	
2265301.9146	10285639.4444	VSP-15	0	Random	
2264833.7042	10285919.5649	VSP-16	0	Random	
2265476.4405	10285483.6637	VSP-17	0	Random	
2265625.4932	10285831.6183	VSP-18	0	Random	
2265068.7330	10285656.2455	VSP-19	0	Random	
2264936.0599	10285623.3110	VSP-20	0	Random	
2265514.4665	10285663.3566	VSP-21	0	Random	
2265458.2032	10285945.5990	VSP-22	0	Random	
2265066.2328	10286016.7997	VSP-23	0	Random	
2265085.2622	10285636.6912	VSP-24	0	Random	
2264799.7844	10285778.3154	VSP-25	0	Random	
2265505.2629	10285953.7490	VSP-26	0	Random	
2265218.2016	10285936.4287	VSP-27	0	Random	
2265369.7326	10285690.3660	VSP-28	0	Random	
2265075.2469	10285634.8206	VSP-29	0	Random	
2265003.4862	10286002.0137	VSP-30	0	Random	
2265352.9186	10285889.5687	VSP-31	0	Random	
2264877.7457	10285910.0798	VSP-32	0	Random	
2264973.4826	10285804.1923	VSP-33	0	Random	
2265584.5676	10285612.5624	VSP-34	0	Random	
2265334.9627	10285491.0034	VSP-35	0	Random	
2265096.8930	10285495.7522	VSP-36	0	Random	
2264983.5288	10285491.0735	VSP-37	0	Random	

Figure 4.16. Coordinates Display of Sampling Locations

4.6 Multiple Displays

Multiple displays can be brought up on the same screen. Table 4.3 lists the options available under main menu item **Window.**

Table 4.3. Window Menu Commands

New Window	Creates a new window that views the same project
Cascade	Arranges windows in an overlapped fashion
Tile	Arranges windows in non-overlapped tiles.
Arrange Icons	Arranges icons of closed windows
Double Window	Shows map view and graph view
Triple Window	Shows map, graph, and report views
Quad Window	Shows map, graph, report, and coordinate views

The user can select the **QUAD WINDOW** button from the toolbar for a quick way to display the Quad Window. Figure 4.17 shows the results of the **Quad Window** option.

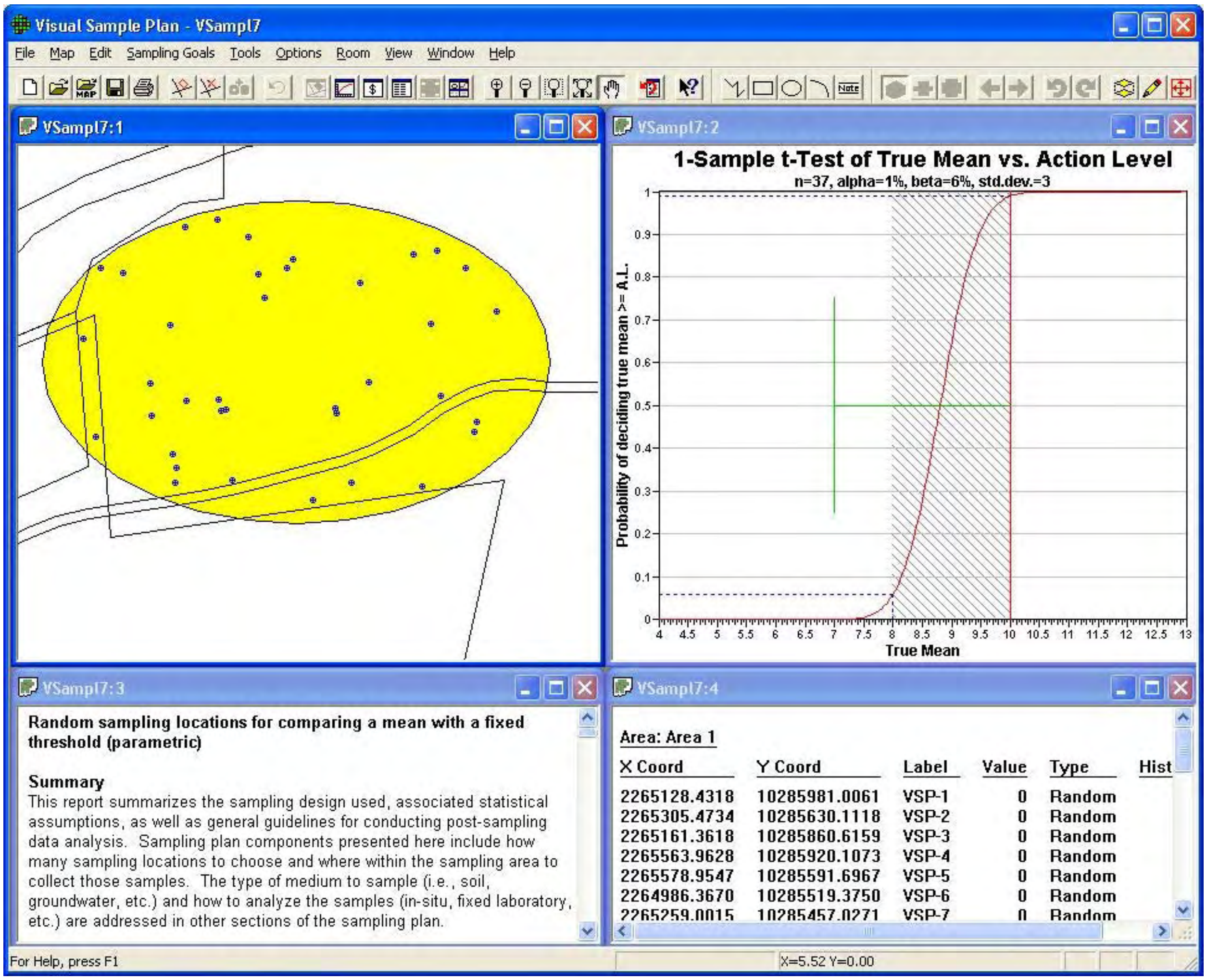


Figure 4.17. Quad Display of Map, Graph, Report, and Coordinates on Same Screen

To summarize, in Figure 4.18 we show the selection of a **Sampling Goal** and sample type **(Simple Random Sampling),** we have entered the **DQO inputs** into the dialog box, **Applied** the design to our **Sample**

Area, and displayed the **Map**, **Graph**, **Report**, and Coordinates simultaneously using the **Quad Window** from the Windows menu.

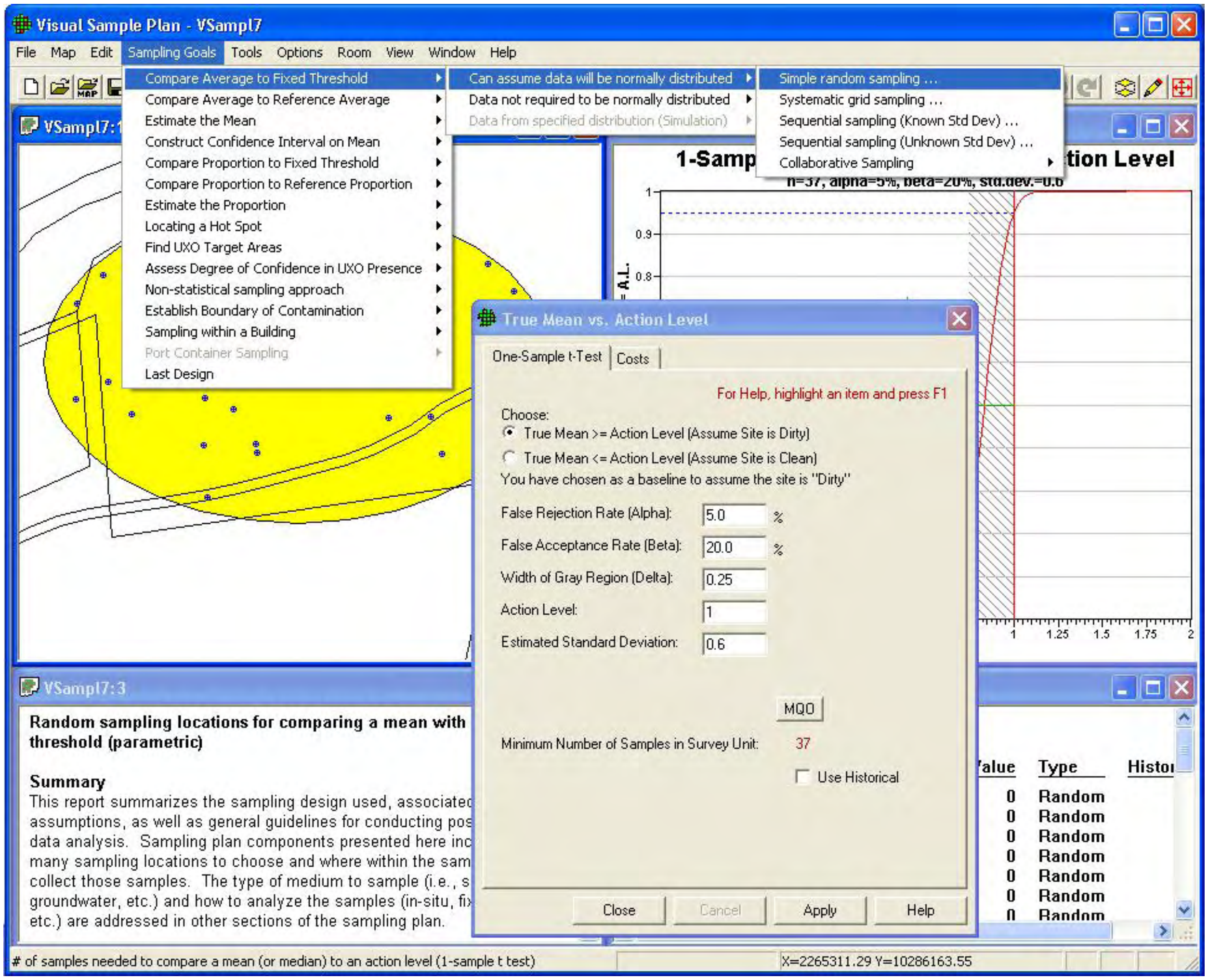


Figure 4.18. Combined Display of VSP Inputs and Outputs

4.7 Room View

Using **View** > **Room View** displays the current room when working with rooms. This is covered in Chapter 6.

4.8 3D View

The 3D view allows for a three-dimensional view of the map. If the project contains rooms or 3D areas, they will be shown with proper perspective height. Figure 4.19 shows a building having many rooms shown in the 3D View.

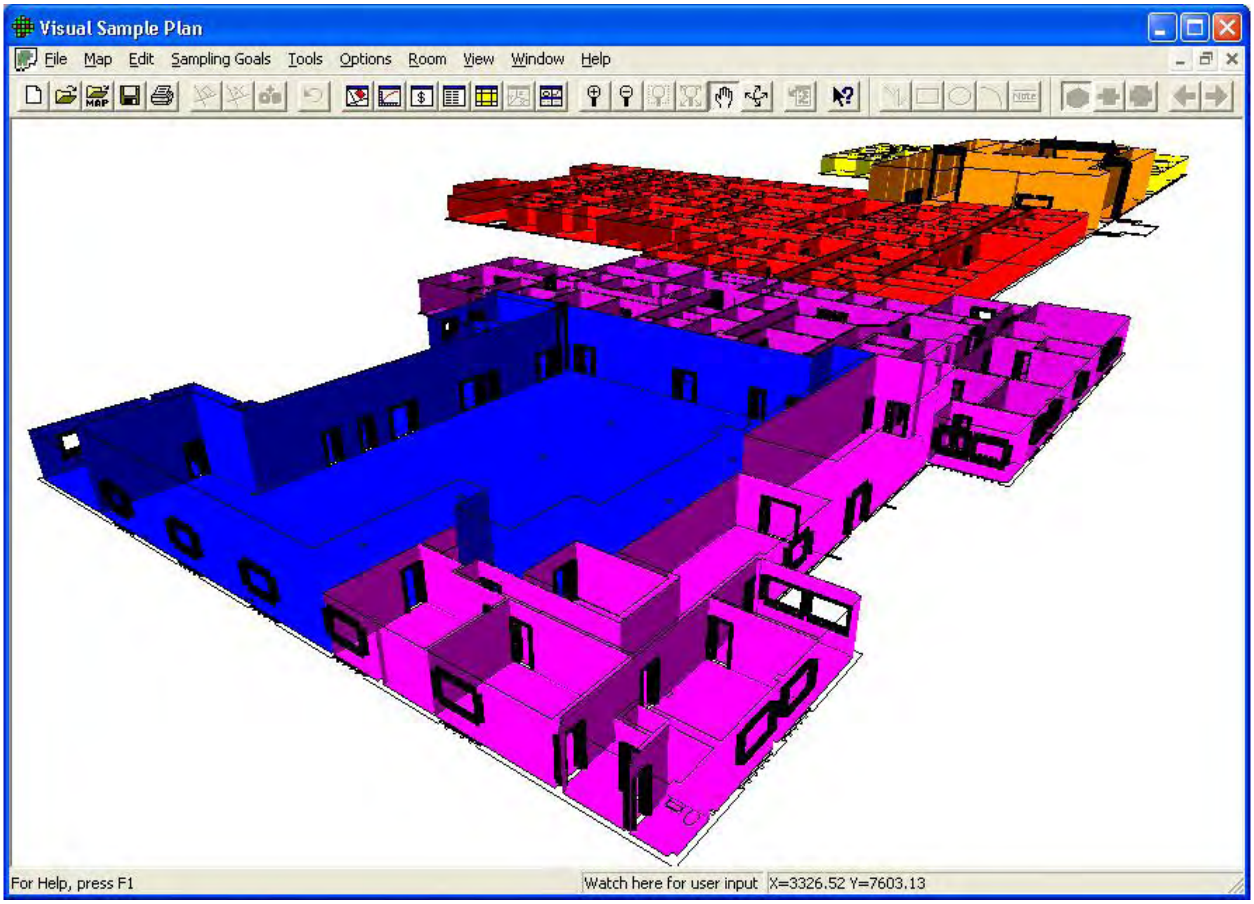


Figure 4.19 3D View with many rooms

For navigation, the 3D View uses 3 of the tools used by the Map View (Zoom In, Zoom Out and Pan). It also introduces a new navigation tool: the Rotate / Tilt tool.

When using the Rotate / Tilt tool (**View > Rotate** on the menu), the cursor becomes a double-ended curved arrow. If you move the cursor to the left edge of view, the tool becomes a Tilt tool. Press and hold the left mouse button while moving the cursor up or down to tilt the view. If you move the cursor away from the left edge of the view, the tool becomes a Rotate tool. Press and hold the left mouse button while moving the cursor around to rotate the view. If the map contains rooms, the view rotates around your point of view (to facilitate navigating through buildings), otherwise the view rotates around the center of the view.

5.0 Extended Features of VSP

VSP has many extended features that will be discussed in this section. The beginning user may not need these features, but a more experienced user will find them invaluable. These features expand on VSP's core capabilities. They are useful once a user has identified a basic sampling design and now wants to explore variations of the design, explore features of the design that are not part of the initial selection parameters, and add more capability to VSP.

The extended features fall into three categories:

- Features found in Main Menu items: **Tools**, **Options**, and **View**,
- Features found in the Dialog Box for individual sampling designs, e.g., the **Costs Tab**, and the **Data Analysis Tab,** and
- Multiple Areas to be Sampled

5.1 Tools

5.1.1 Largest Unsampled Spot

If VSP has generated a sampling design for a Sample Area and you want to know the largest unsampled area, VSP can display this information. The largest unsampled spot is defined as the largest circle that will fit inside a Sample Area without overlapping a sample point.

In Figure 5.1, we opened the VSP Project File *Example1.vsp* included with the standard VSP installation. From the Main Menu we select **Tools > Largest Unsampled Spot > Find.** A dialog box shown in Figure 5.1 in the insert tells you that VSP will search the Sample Area to find the largest circle that would fit into the unsampled area. The user is given the option of specifying the accuracy of the circle's radius, whether to consider area corners as additional sample points, and whether to allow the spot to overlap the Sample Area. After hitting the **OK** button, VSP searches the Sample Area, and places the spot on the Map, and displays an Information Box that says the radius of this circle is **205.22 ft**. (see Figure 5.2).

Two other displays are available: **Show Size** and **Inside Area.** The **Show Size** displays the Information Box shown in Figure 5.2. **Inside Are**a brings up the Information Box shown in Figure 5.3. It says that 100% of the circle is within the Sample Area. If the option to allow the largest unsampled spot to overlap the Sample Area edges had been selected, there may be situations where the circle extends beyond the boundary of the Sample Area resulting in a percentage less than 100%.

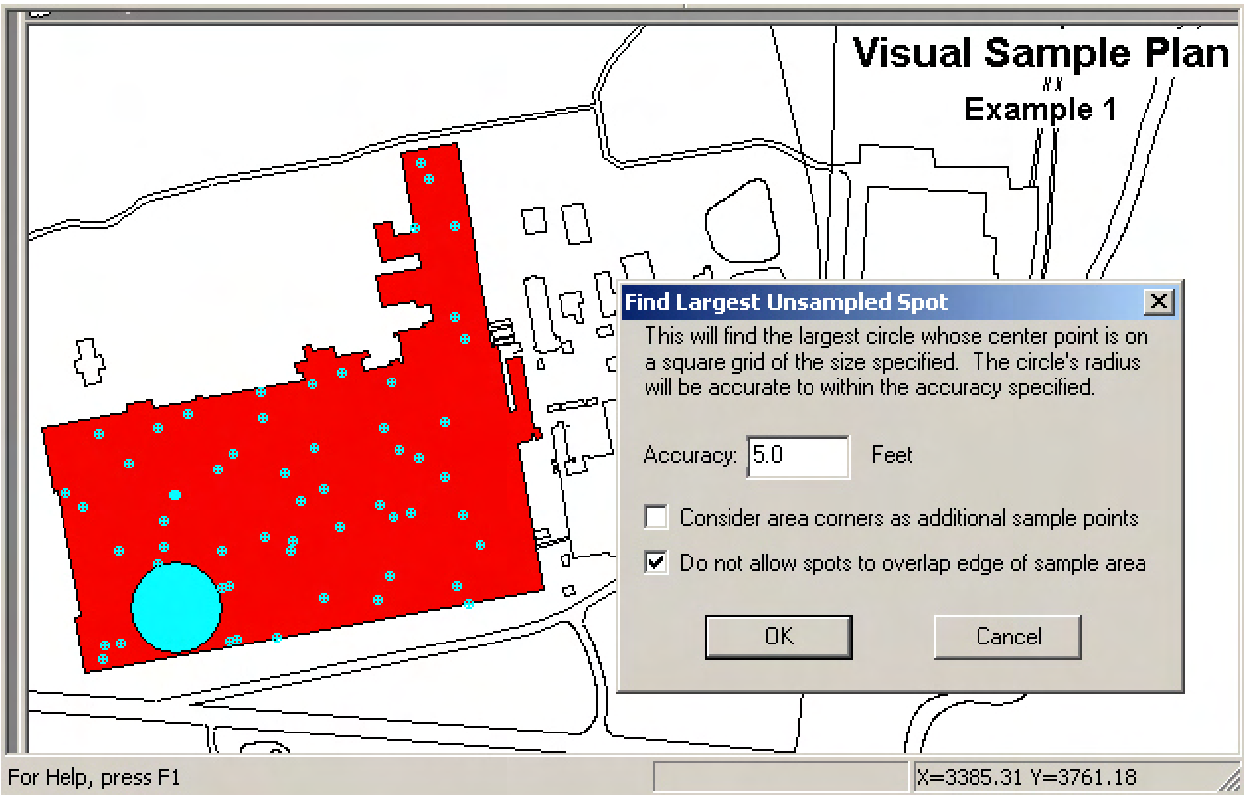


Figure 5.1. Largest Unsampled Spot Displayed on Map

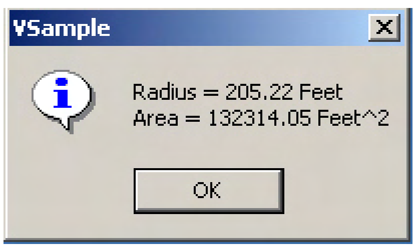


Figure 5.3. Information Box for Largest Circle That Would Fit Within an Unsampled Area

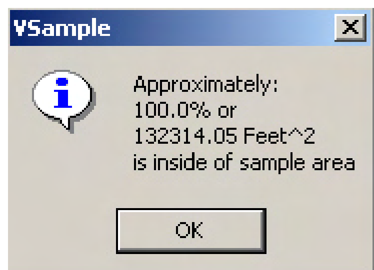


Figure 5.2. Information Box Showing Percentage of Circle Within the Sample Area

5.1.2 Reset Sampling Design

This command clears the current sampling design and removes all samples from the map (including unselected sample areas).

5.1.3 Measure Distance

Use this tool to measure distances on the map. After selecting this command, the cursor will become a ruler. Click on the map or enter a location (x, y) on the keyboard to anchor the first point. A line will be drawn from the anchor point to the cursor as you move the mouse. The status bar will also indicate the distance from the anchor point to the cursor. After clicking on a second point or entering a second point on the keyboard, a dialog will appear displaying the distance. In Figure 5.4, we see that the distance from the sampling point to the building edge is **547.33 ft**.

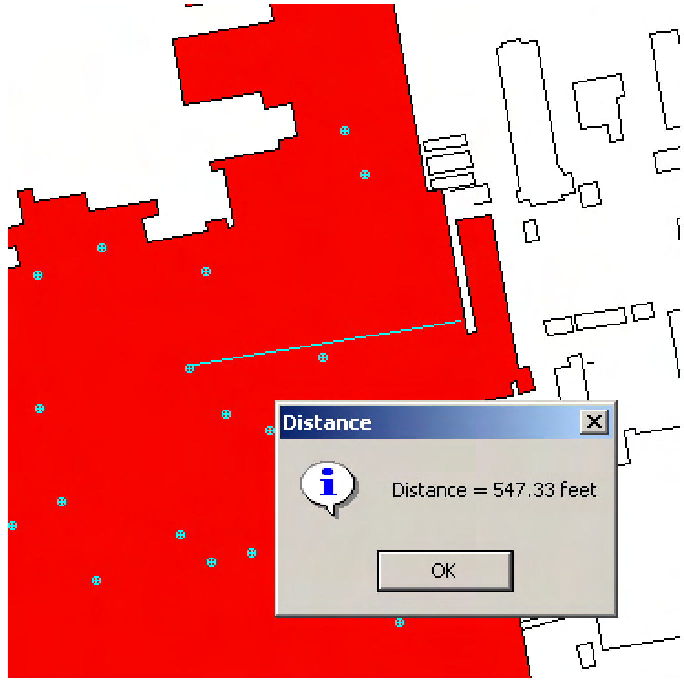


Figure 5.4. Measuring Tool in VSP

Hold the Shift key down to attach either point to an existing point on the map.

5.1.4 Make Sample Labels

Individual samples can have labels and values associated with them. This tool lets the user design the sample label. Selecting **Tools > Make Sample Labels** brings up the Dialog Box shown in Figure 5.5. VSP assumes the user will want to assign a unique number to each sample within a Map, so all labels start with "VSP-<NNN>". Other information can be added to the label, such as the Local X Coordinate and Local Y Coordinate as shown in Figure 5.5, by selecting the information variable names on the list and hitting the **Add** button. (The information can also be added by double-clicking on the list item or by typing in the label format edit box.) Once the **OK** button is pushed, the user sees the current set of Sample Labels in Map View.

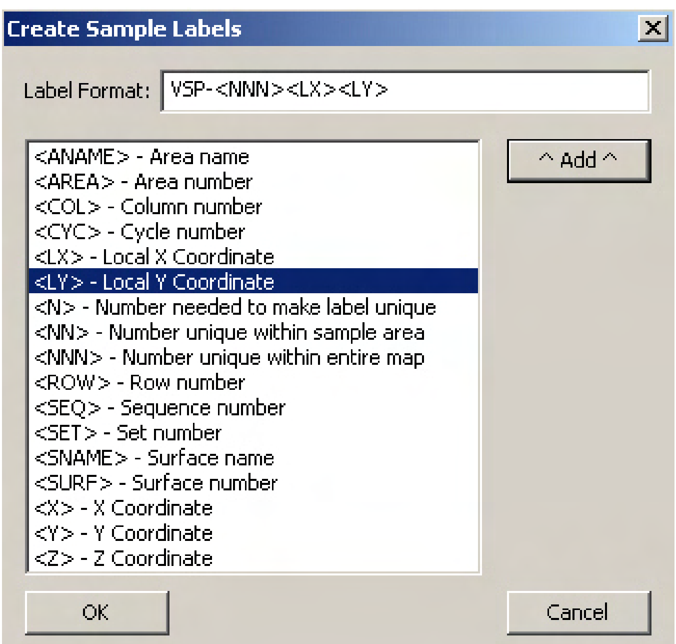


Figure 5.5. Dialog Box for Creating Sample Labels

Sample labels are discussed in Section 2.4

5.1.5 Geostatistical Analysis

This command allows for a geostatistical analysis of sites where transect and anomaly (UXO) data have been collected. For a detailed explanation on geostatistical mapping of anomaly density, see Section 7.3.

5.1.6 Correlate Analytes

This VSP module aims to provide the VSP user with correlation methods, graphical displays, and an automated report for datasets with a large number of analytes (variables) to assess if some analytes could be eliminated or measured less frequently to reduce analytical costs. Figure 5.6 shows the **Correlate Analytes** dialog.

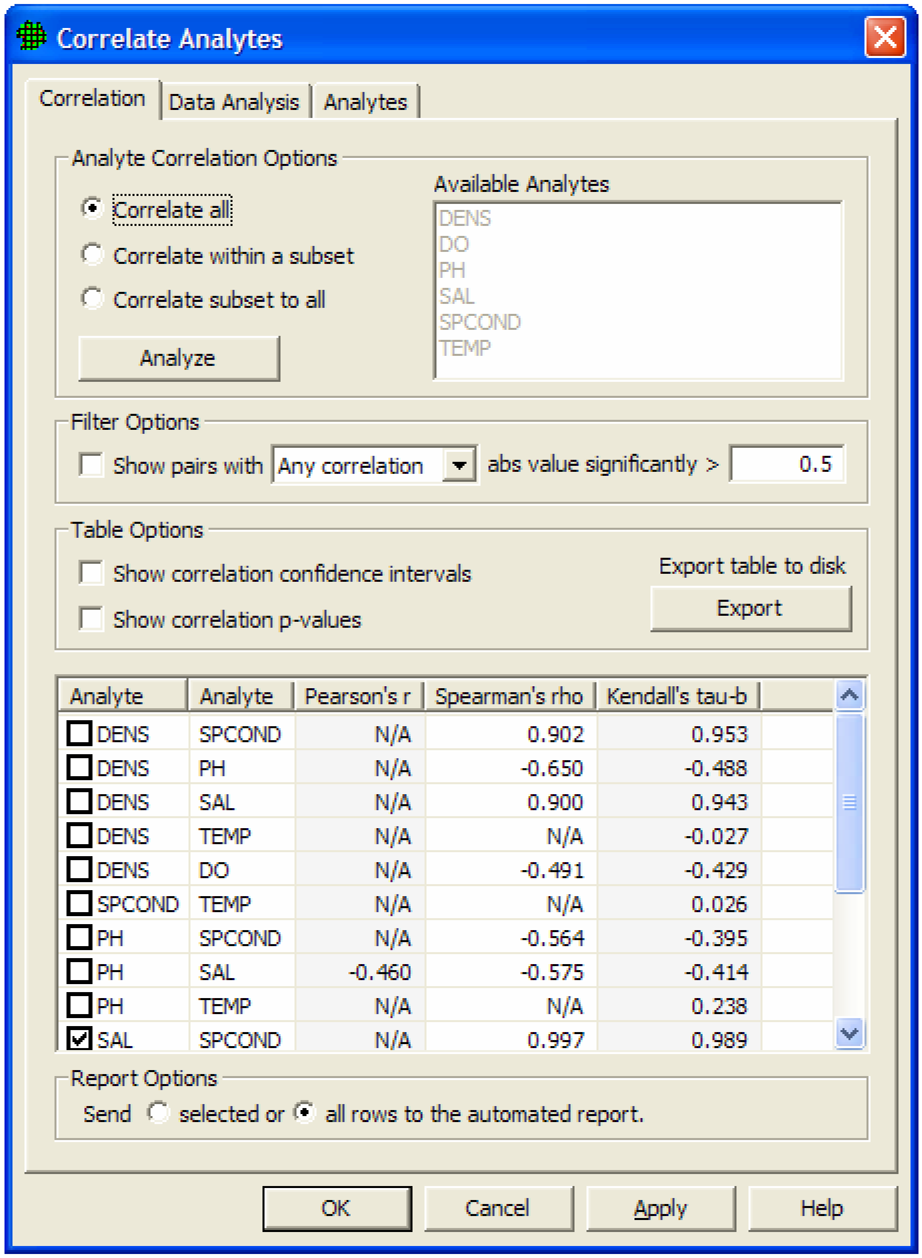


Figure 5.6 Correlate Analytes dialog

There are three **Analyte Correlation Options** available for how to choose analytes and display correlations. **Correlate All** will display all pairs of correlations for all available analytes. For the remaining two options, analytes are selected from the list of **Available Analytes**. **Correlate within a subset** will display all pairs of correlations for the analytes selected. **Correlate subset to all** will display all pairs of correlations from the list of available analytes which involve at least one of the analytes selected. Clicking "Analyze" populates the table using the specified option.

Under **Filter Options** in Figure 5.6, several filters are available for screening out correlations whose absolute values do not significantly exceed a threshold. Clicking the box next to **"Show pairs with"** activates this filter. Then chose the correlations of interest from the drop down menu: **Any Correlations**, **All Correlations**, **Pearson's *r***, **Spearman's rho**, or **Kendall's tau-b**. **Any Correlations** implies that if any of Pearson's r, Spearman's rho, or Kendall's tau-b have absolute values statistically greater than the value specified, the pair of analytes will be displayed. **All Correlations** implies that all three correlations must have absolute values statistically greater than the value specified. When **Pearson's *r***, **Spearman's rho**, or **Kendall's tau-b** are selected, only the correlation chosen is tested against the value specified.

The table in Figure 5.6 shows pairs of analytes in the first two columns, and is populated with three correlations: **Pearson's *r***, **Spearman's rho**, and **Kendall's tau-b**. Under **Table Options**, clicking the **Show correlation confidence intervals** box will add confidence intervals to the table for all three correlations. Clicking the **Show correlation p-values** box will show the p-value for each correlation for a test to determine if the correlation is significantly different from zero. Clicking **Export table to disk** allows for the table to be exported outside of VSP.

Double-clicking on any row in the table displays a graph of the pair of analytes for that row like the one shown in Figure 5.7. Checking the **Add graph to report** box (Figure 5.7), or checking the box in the left-hand column of the table (Figure 5.6) will insert this plot into the automated report. By default, the entire table is displayed in the report, but graphs are not automatically displayed. Only pairs of analytes with checked rows in the table have graphs included in the automated report. To display only checked rows in the table within the automated report, select the first button under **Report Options**. Otherwise the report will display all show all pairs of analytes shown within the table in the **Correlate Analytes** dialog.

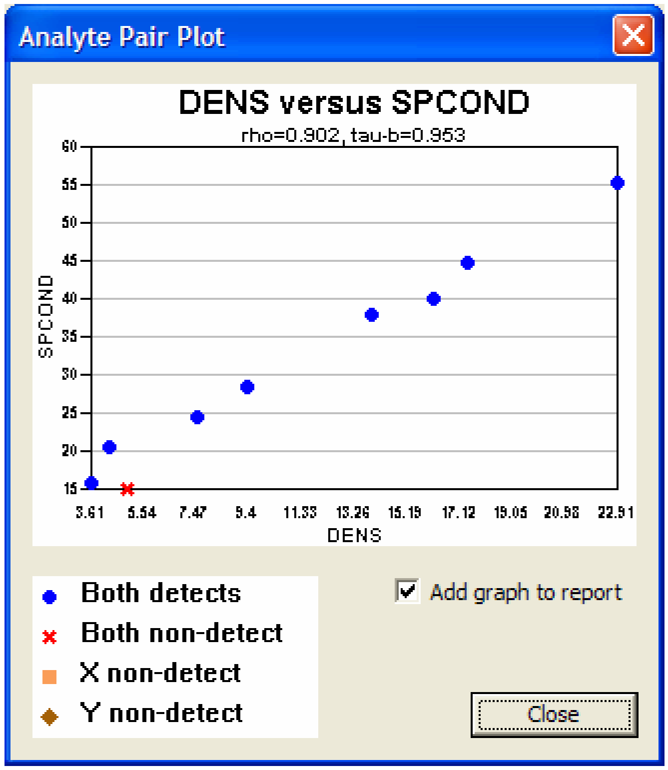


Figure 5.7 Analyte Pair Plot

5.2 Options

5.2.1 Random Numbers

VSP allows the user two options when selecting how random numbers are generated. The random numbers are used to pick coordinates for sampling locations when the design calls for either a random-start grid or random placement of all points. The user selects the desired random number generator using **Options** > **Random Numbers** from the Main Menu. The two options are **Pseudo-Random Numbers** and **Quasi-Random Numbers.** The user "toggles" between these two options. This is shown in Figure 5.8. Note that once an option is selected, it remains active until changed. VSP is initialized with the **Pseudo-Random Numbers** option active.

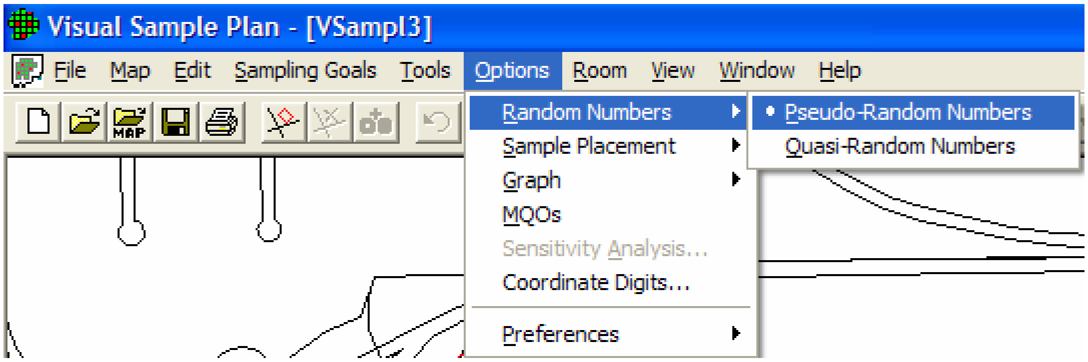


Figure 5.8. Menu for Selecting Type of Random Number Generator

Sampling locations (i.e., the x and y coordinates of the location) chosen with a pseudo-random number generator are not restricted in any way. The first location chosen and the tenth location chosen can be right next to each other or far apart, like throwing darts at a dart board. The locations where the darts hit can be clumped together or spread out, depending on chance.

Quasi-random numbers are generated in pairs. One member of the pair is used for the X coordinate; the other member is used for the Y coordinate. The sequence of paired numbers is generated in such a way that sample points tend to be spread evenly over a sample area. VSP's quasi-random-number generator uses Halton's Sequence. For a discussion of the algorithms used for both the pseudo- and the quasi-random number generator, see *Version 2.0 Visual Sample Plan (VSP) Models and Code Verification* (Gilbert et al. 2002).

If the current sampling design is being added to a study area with existing sampling locations, the quasi--random number generator will have no knowledge of those locations and might by chance put a new sampling location right next to an existing location. See the **Adaptive-Fill** option in Section 5.2.2 to handle the problem of avoiding existing sampling locations.

5.2.2 Sample Placement

The Adaptive-Fill option allows the addition of "random" sampling locations in such a way as to avoid existing sampling locations. Adaptive Fill has to do with the placement of the sampling locations, not the number of samples. The basic idea is to place new sampling locations so as to avoid existing locations and still randomly fill the Sample Area. The current Sampling Design option determines the number of locations.

VSP usually places new sampling locations using the default option, **Options > Sample Placement > Regular Random**. When Regular Random is selected, the sampling locations produced by either of the two random number generators discussed in Section 5.2.1 are placed in the Sample Area without regard to pre-existing samples. In fact, VSP removes all previous sampling locations prior to placing the new set of sampling locations.

When the **Options > Sample Placement > Adaptive-Fill** option is selected, all pre-existing sampling locations are left in place, and new sampling locations are placed in the Sample Area using an algorithm to maximally avoid preexisting sampling locations. The Adaptive-Fill algorithm can be used with either random number generator. The Adaptive-Fill option is shown in Figure 5.9.

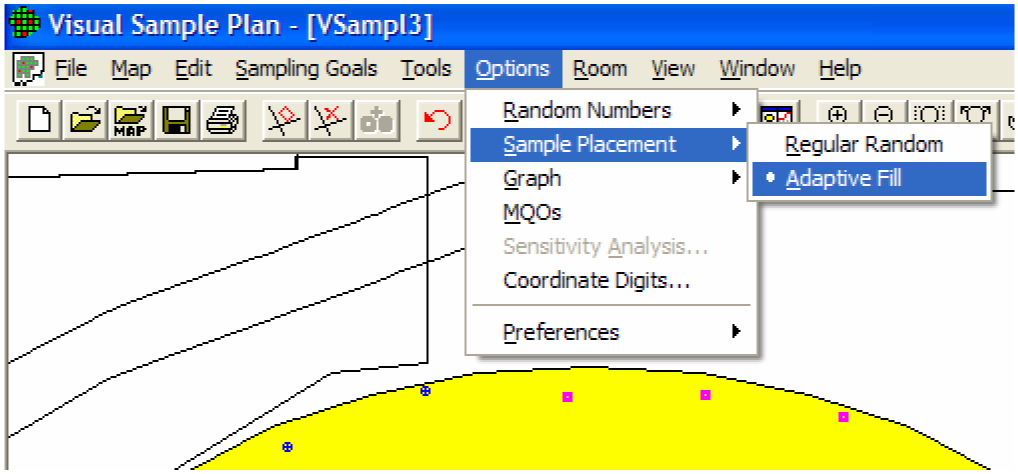


Figure 5.9. Adaptive-Fill Option for Sample Placement (Shown Here with Sample Area from Millsite Map)

Note that in Figure 5.9 the original sampling locations are marked with a circular symbol. In contrast, the Adaptive-Fill sampling locations are marked with a square symbol. If you right-click on a sampling-location symbol, a Sample Information dialog will display the type of sample, the coordinates, and a label input field. The label input field allows a specific sampling location to be given an ID number or remark.

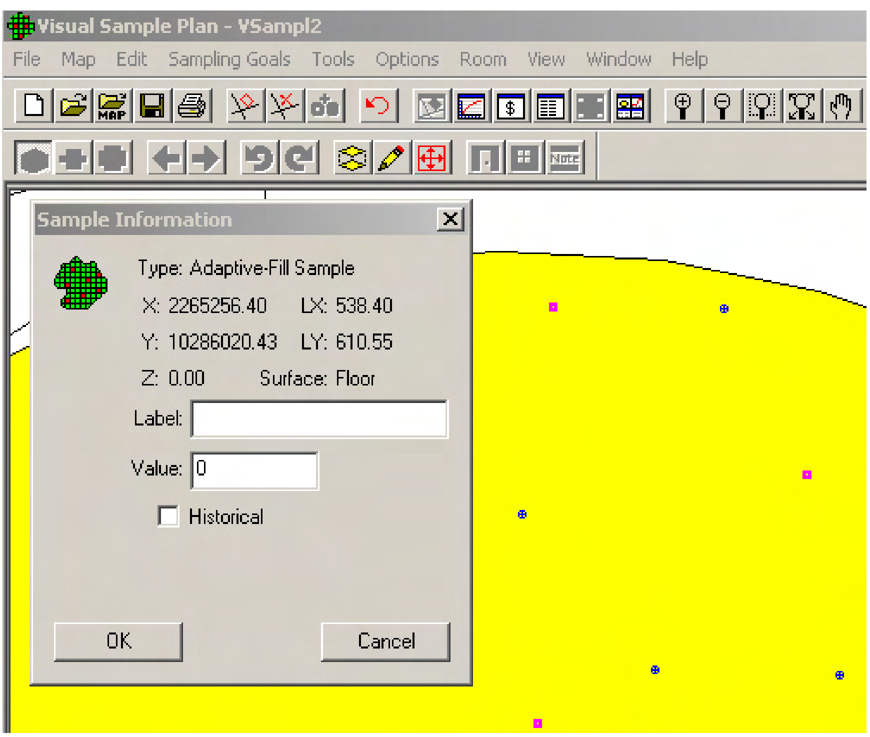
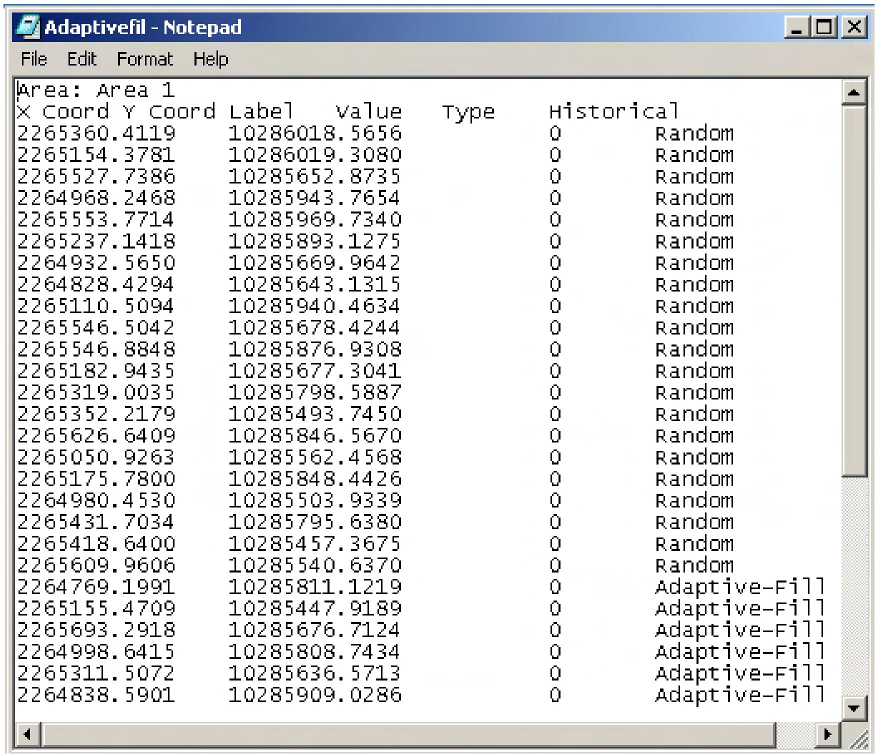


Figure 5.10. Sample Information Window Displayed When the User Right-Clicks on Selected Sample Points on Map

The label information is displayed in the Sample Information dialog, the report view, and the coordinate view. The label is also exported along with other sample information when exported to a text file (see Figure 5.11). See Figure 5.10 for an example of right-clicking on an Adaptive-Fill sampling location.

If the sampling locations are exported to a text file using **Map** > **Sample Points** > **Export**, an Adaptive-Fill location will be noted and any label the user might have added will be saved. An example text file is shown in Figure 5.11.




```
Area: Area 1
X Coord Y Coord Label   Value   Type    Historical
2265360.4119    10286018.5656           0       Random
2265154.3781    10286019.3080           0       Random
2265527.7386    10285652.8735           0       Random
2264968.2468    10285943.7654           0       Random
2265553.7714    10285969.7340           0       Random
2265237.1418    10285893.1275           0       Random
2264932.5650    10285669.9642           0       Random
2264828.4294    10285643.1315           0       Random
2265110.5094    10285940.4634           0       Random
2265546.5042    10285678.4244           0       Random
2265546.8848    10285876.9308           0       Random
2265182.9435    10285677.3041           0       Random
2265319.0035    10285798.5887           0       Random
2265352.2179    10285493.7450           0       Random
2265626.6409    10285846.5670           0       Random
2265050.9263    10285562.4568           0       Random
2265175.7800    10285848.4426           0       Random
2264980.4530    10285503.9339           0       Random
2265431.7034    10285795.6380           0       Random
2265418.6400    10285457.3675           0       Random
2265609.9606    10285540.6370           0       Random
2264769.1991    10285811.1219           0       Adaptive-Fill
2265155.4709    10285447.9189           0       Adaptive-Fill
2265693.2918    10285676.7124           0       Adaptive-Fill
2264998.6415    10285808.7434           0       Adaptive-Fill
2265311.5072    10285636.5713           0       Adaptive-Fill
2264838.5901    10285909.0286           0       Adaptive-Fill
```

Figure 5.11. Sample Exported Text File of Sampling Locations

5.2.3 Graph

Graphs can be displayed with many different options. Figure 5.12 shows the options that can be selected using **Options > Graph**. Options are selected by clicking the option on or off. Once selected, that option will be in place for all Graphs. Note that we saw these same options in Chapter 4, Figure 4.3, by right-clicking on a Graph. Table 4.2 describes these options in more detail.

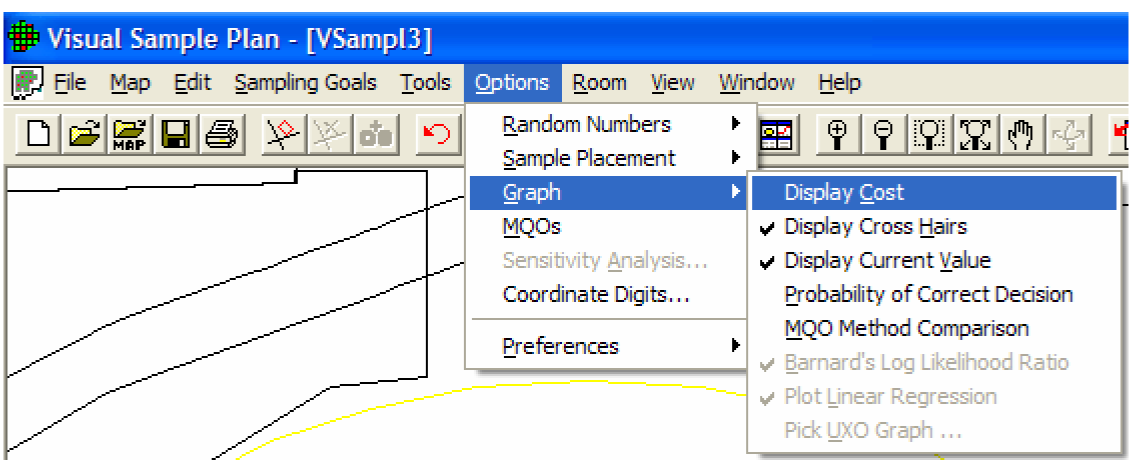


Figure 5.12. Graph Options

5.2.4 Measurement Quality Objectives (MQOs)

The Measurement Quality Objectives (MQO) module in VSP provides a way to extend the sampling design to consider not only the number and placement of samples in the field but also what happens in the measurement or analysis process. After all, it is the final result of the “measured sample value” that gets reported back to the project manager and used in statistical tests to make a decision.

There is a trade-off between taking more samples using a crude (i.e., less precise) measuring device vs. taking fewer samples using a precise measuring device and/or method. This is because total decision error is affected by the total standard deviation of the samples. The total standard deviation includes both sampling variability and analytical measurement variability.

There is also a trade-off between taking more measurements (i.e., replicate measurements) when using these less precise analytical measuring devices and/or methods vs. taking few measurements and using more precise analytical measuring devices and/or methods. The MQO module in VSP lets the user play “what-if” games with various combinations of sampling standard deviation, analytical (i.e., measurement) standard deviation, number of analyses (i.e., replicates) per sample, and number of samples to take. More discussion of this topic and the sample size equations behind the VSP calculations can be found in *Version 2.0 Visual Sample Plan (VSP) Models and Code Verification* (Gilbert et al. 2002).

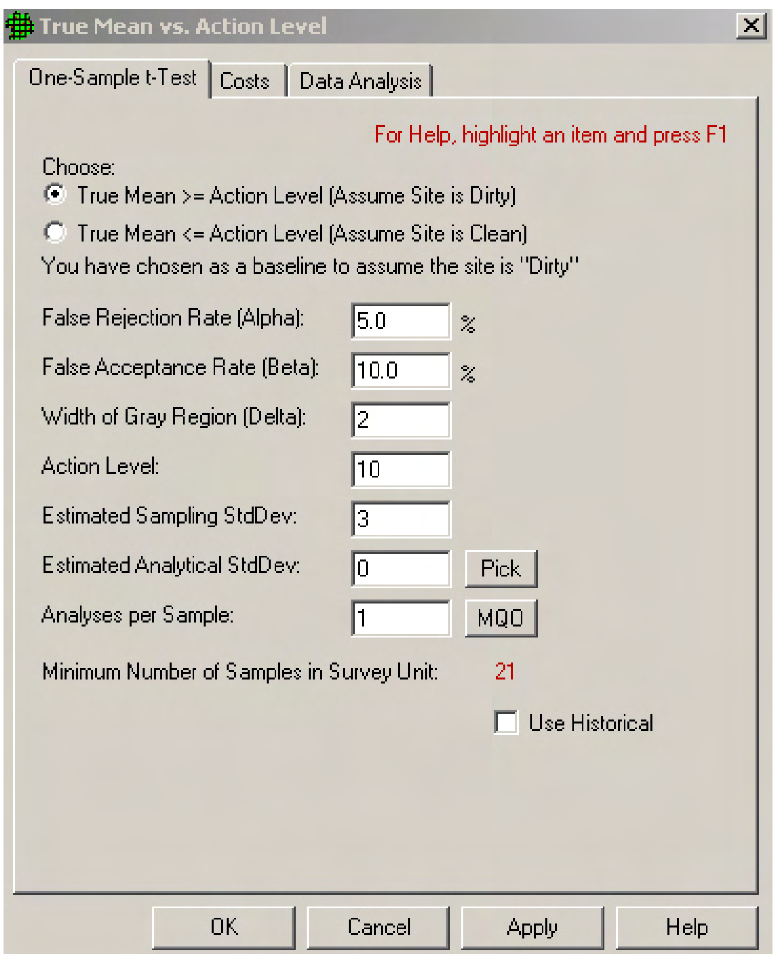


Figure 5.13. MQO Input Dialog Box with Default Values Displayed

The MQO option is selected from the dialog that pops up after a Sampling Design has been selected. The MQO option can also be toggled using **Options** > **MQOs** from the main menu. In Figure 5.13, we see a dialog box that contains the MQO button (**Sampling Goals** > **Compare Average to Fixed Threshold**). This dialog box allows you to provide additional inputs, such as the analytical standard deviation and number of analyses per sample. There is also a **Pick** button (not active at this time but planned in future versions of VSP) to provide access to a library of standard analytical methods with their reported analytical standard deviations.

Note that the default values are **0** for the **Estimated Analytical Standard Deviation** and **1** for the **Analyses per Sample.** This means that the user-selected analytical or measurement method does not add a significant component of variability to the total standard deviation; i.e., the method provides essentially the same numeric value when repeated measurements are made on a sample. Using the input parameter values shown in Figure 5.13 and with these default MQO values, we get n = 21 samples.

Now let's start changing the MQO input values. First, we change the **Estimated Analytical Standard Deviation** to **3.** We still take only one analysis per sample. We see VSP now tells us we need to take **40** field samples to obtain the desired error rates we specified. This is shown in Figure 5.14.

If we take two repeated measurements of each sample **(Analyses per Sample** set to **2),** we see in Figure 5.15 that the number of field samples is now only **31.**

You can try different values in the MQO input boxes and see the effect on the resulting number of field samples.

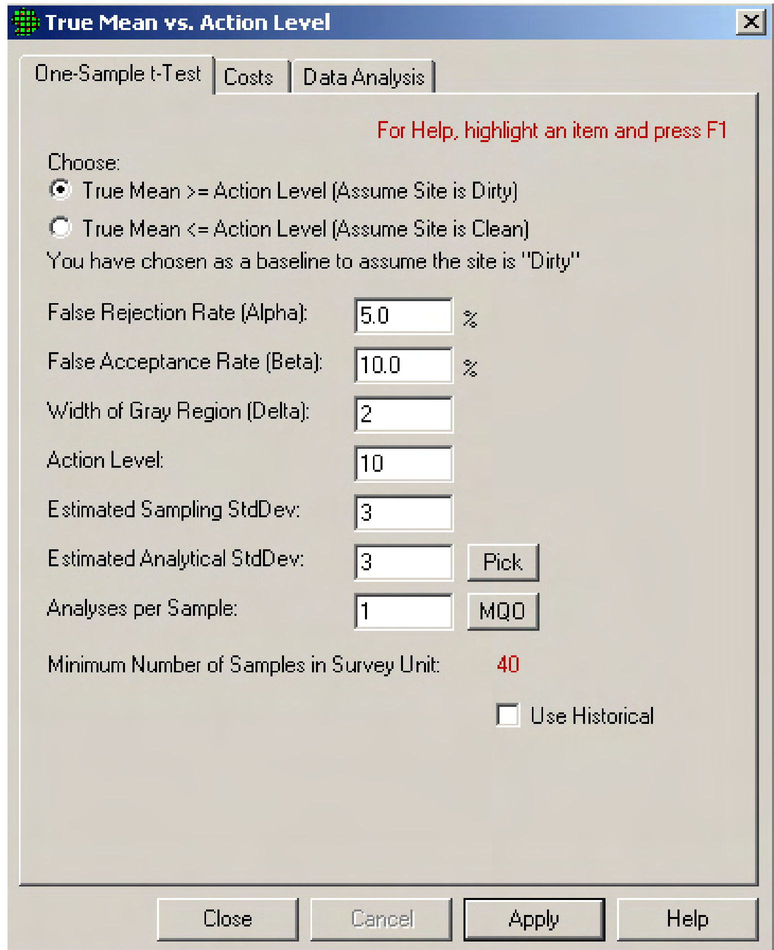


Figure 5.14. MQO Input Dialog Box Showing Positive Value for **Estimated Analytical Standard Deviation** with **1 Analysis per Sample**

When you select the **COSTS** tab at the top of the screen, a new display and set of inputs is shown. This is shown in Figure 5.16. In this dialog box, we can enter costs for **Field Collection** (shown here as **$100** per sample) and **Analytical Cost per Analysis** (shown here as **$400** per analysis). This screen also provides a **Cost Comparison** between two possible options, Analytical Methods A and B. We see the Method A Analytical Standard Deviation of **3** that we entered on the previous screen. We can also enter an Analytical Standard Deviation for Method B. Initially, VSP displays the default values of **0** for Method B as shown in Figure 5.16. VSP displays the comparison for one, two, or three replicate analyses for only Method A because Method B has an analysis cost of $0.00.

Next we show input values for Method B. Here, we enter a **Method B Analytical Standard Deviation** of **4** (somewhat higher than Method A), but with a lower **Cost per Sample** (shown here as **$100).** In Figure 5.17 we see that the Method Comparison is now filled in with the new values. The lowest cost option (Method B with 1 Analysis per Sample) is highlighted in blue.

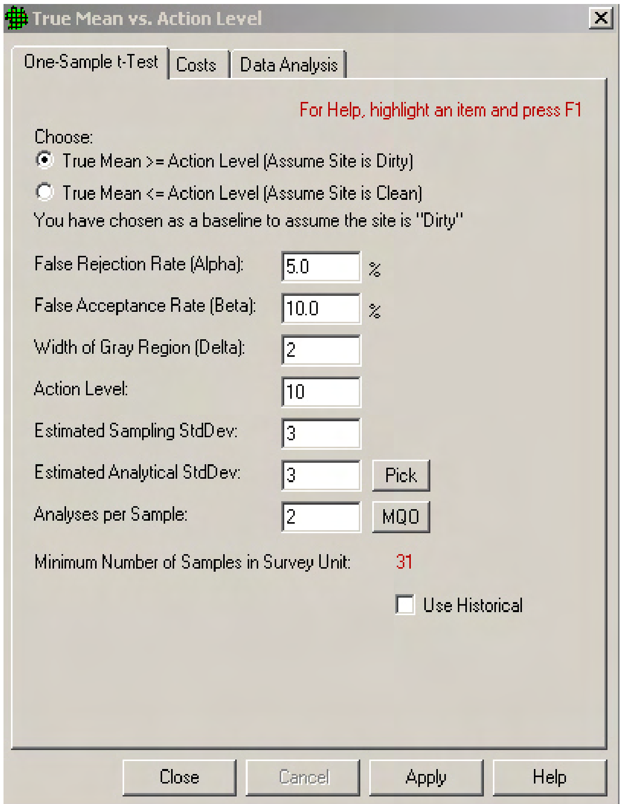


Figure 5.15. MQO Input Dialog Showing Positive Value for **Estimated Analytical Standard Deviation** with **Multiple Analyses per Sample**

A graphical comparison of the analytical methods is shown an overlay on the Decision Performance Curve when **Options > Graph > MQO Method Comparison** is checked. You must go to **View > Graph** to see the chart. Figure 5.18 shows an example.

The yellow circle is placed above the lowest-cost sampling design that meets the objectives. In this case, the circle is above a green bar representing the cost of using sampling design Method B with one analysis per sample.

5.2.5 Sensitivity Analysis

This option accesses the sensitivity analysis parameters on the Report View. The sensitivity

Notice that the lowest cost sampling design for this problem has the most field samples, $n = 55$. This is because Method B has a very low analysis cost of only \$100 vs. the much higher cost for Method A of \$400. Therefore, Method B can reduce the uncertainty in the final decision by allowing many more field samples to be analyzed compared with Method A.

Note also that the sampling design will not automatically change to the Method B case highlighted in blue. If you want a sampling design based on Method B, you must update the **Analytical Cost per Analysis** for Method A to match the Method B cost.

Then return to the **One-Sample t-Test** tab, change the **Estimated Analytical Standard Deviation** value to match the Method B value, and press the **Apply** button to get the Method B-based sampling design.

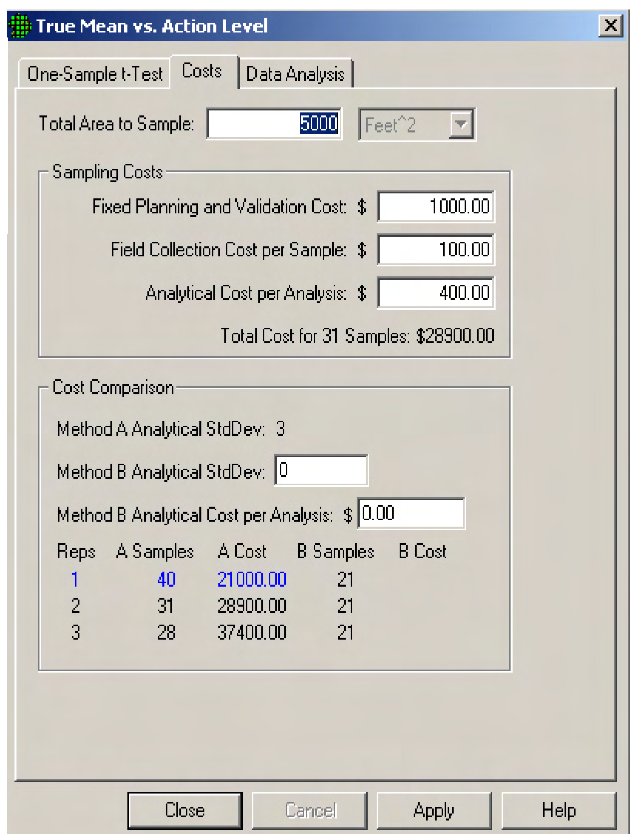


Figure 5.16. Cost Input Dialog Box for MQO Option

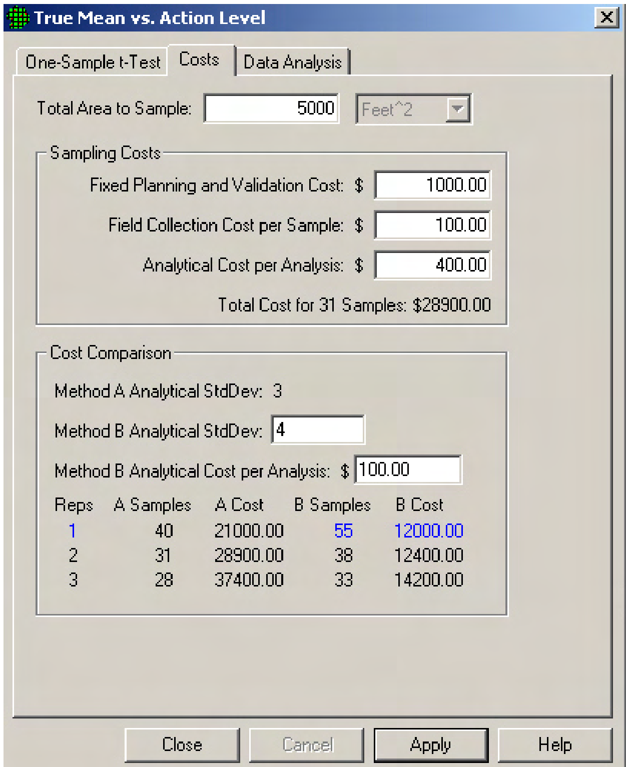


Figure 5.17. Display of **Cost Comparison** for Method A and Method B from MQO Module

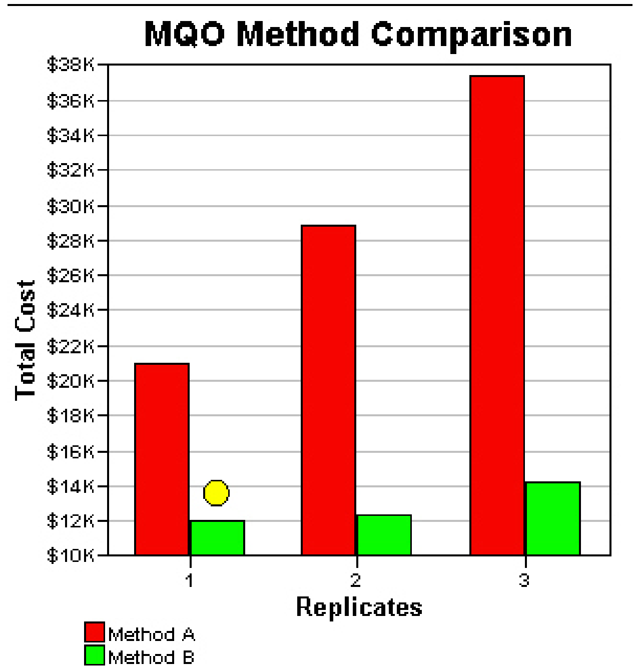
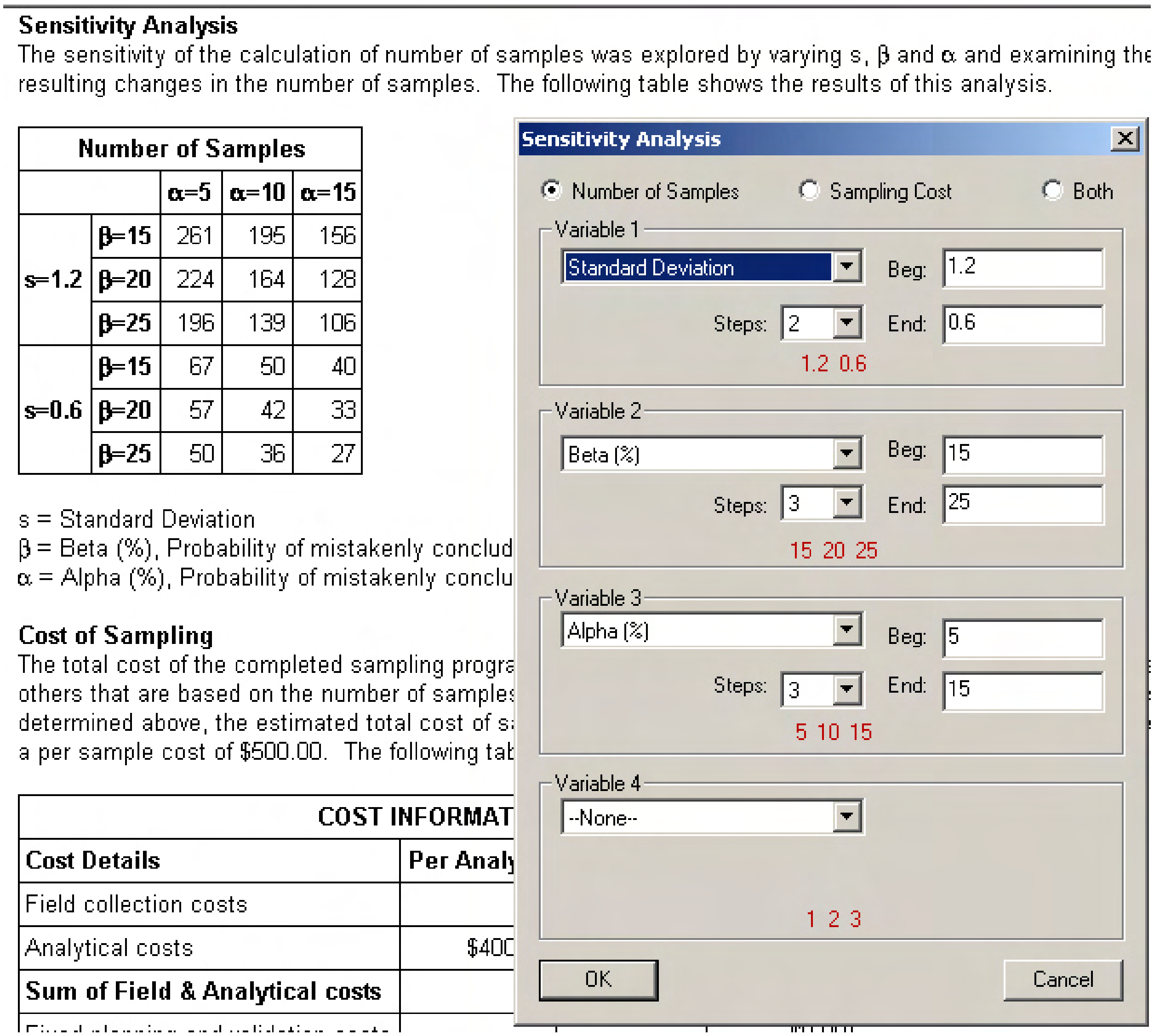


Figure 5.18. MQO Method Comparison Chart

analysis parameters may also be accessed by right-clicking on the Report View itself. The example shown in Figure 5.19 is from the VSP Project File *Example1.vsp*. With **View** > **Report** selected, scroll down to the section on Sensitivity Analysis. Now select **Options** > **Sensitivity Analysis**, and the Dialog Box shown in Figure 5.19 is displayed. The user can do sensitivity analysis on up to 4 variables (only 3 are shown here), can select a starting and ending value for each variable, and can specify the number of steps for incrementing the variable. VSP displays the values for each step in Red below the Step window. For this example, in Figure 5.19, we say we want to see the number of samples required at values of the Standard Deviation s= 1.2, and 0.6. For each of these levels, we want to look at three levels of Beta, and three levels of Alpha. VSP calculates sample size for each of these 2 x 3 x 3 = 18 options and displays the values in the Table.

This option is a very powerful tool for looking at “what if” scenarios and determining trade-offs for risk and cost. Tables for Number of Samples, Sampling Cost, or both can be displayed. Figure 5.20 shows 4 of the DQO Parameters being changed, and shows the results of the sensitivity analysis for both number of samples and cost.



Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying s, β and α and examining the resulting changes in the number of samples. The following table shows the results of this analysis.

Number of Samples				
		α=5	α=10	α=15
s=1.2	β=15	261	195	156
	β=20	224	164	128
	β=25	196	139	106
s=0.6	β=15	67	50	40
	β=20	57	42	33
	β=25	50	36	27

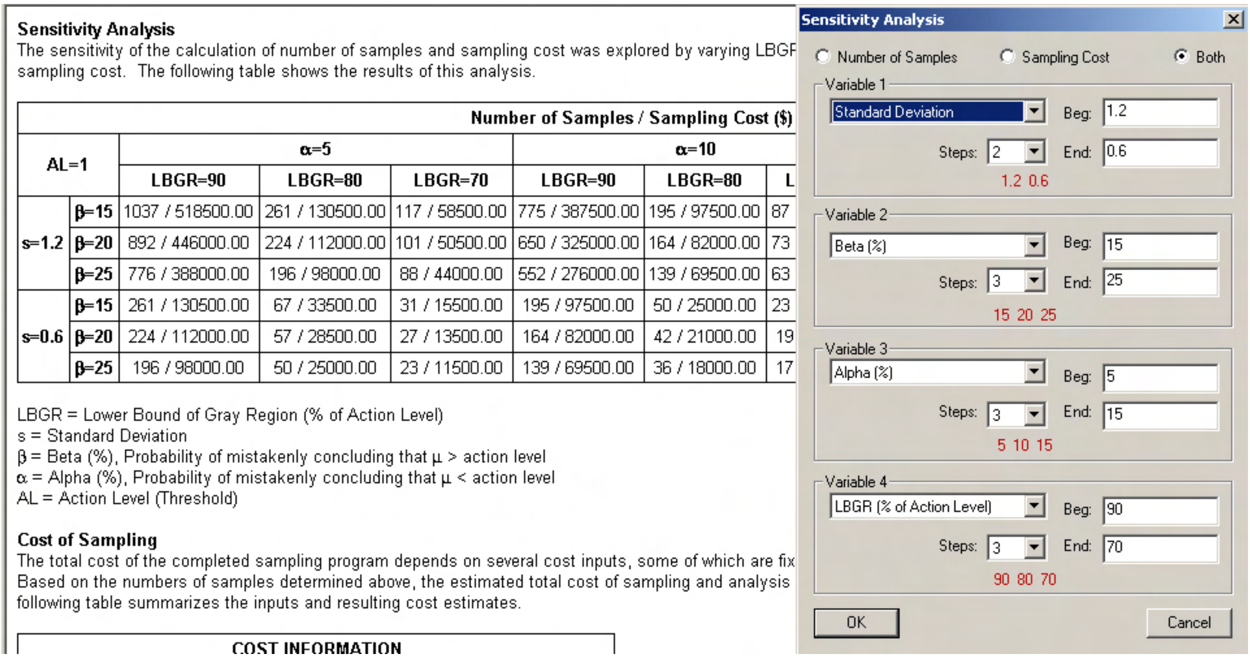
s = Standard Deviation
β = Beta (%), Probability of mistakenly conclud
α = Alpha (%), Probability of mistakenly conclu

Cost of Sampling

The total cost of the completed sampling progra
others that are based on the number of samples
determined above, the estimated total cost of s
a per sample cost of $500.00. The following tab

COST INFORMAT	
Cost Details	**Per Analy**
Field collection costs	
Analytical costs	$400
Sum of Field & Analytical costs	

Figure 5.19. Sensitivity Analysis for 3 DQO Input Parameters. Results are shown for Number of Samples, as displayed in a table in Report View.



Sensitivity Analysis

The sensitivity of the calculation of number of samples and sampling cost was explored by varying LBGR
sampling cost. The following table shows the results of this analysis.

AL=1		Number of Samples / Sampling Cost ($)					
		α=5			α=10		
		LBGR=90	LBGR=80	LBGR=70	LBGR=90	LBGR=80	L
s=1.2	β=15	1037 / 518500.00	261 / 130500.00	117 / 58500.00	775 / 387500.00	195 / 97500.00	87
	β=20	892 / 446000.00	224 / 112000.00	101 / 50500.00	650 / 325000.00	164 / 82000.00	73
	β=25	776 / 388000.00	196 / 98000.00	88 / 44000.00	552 / 276000.00	139 / 69500.00	63
s=0.6	β=15	261 / 130500.00	67 / 33500.00	31 / 15500.00	195 / 97500.00	50 / 25000.00	23
	β=20	224 / 112000.00	57 / 28500.00	27 / 13500.00	164 / 82000.00	42 / 21000.00	19
	β=25	196 / 98000.00	50 / 25000.00	23 / 11500.00	139 / 69500.00	36 / 18000.00	17

LBGR = Lower Bound of Gray Region (% of Action Level)
s = Standard Deviation
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Cost of Sampling

The total cost of the completed sampling program depends on several cost inputs, some of which are fix
Based on the numbers of samples determined above, the estimated total cost of sampling and analysis
following table summarizes the inputs and resulting cost estimates.

COST INFORMATION

Figure 5.20. Sensitivity Analysis for 4 DQO Input Parameters. Results shown for Number of Samples / Sampling Cost ($), as displayed in a table in Report View

5.2.6 Coordinate Digits

Selecting this option (**Options** > **Coordinate Digits**) brings up a dialog box where the user inputs the number of significant digits (after the decimal point) for displaying the X, Y, and Z coordinates in **View** > **Coordinates**.

5.2.7 Preferences

Figure 5.21 shows the Preferences available in VSP. Table 5.1 provides a brief description of each Preference. Consult VSP **Help** > **Help Topics** > **Menus** > **Options menu** > **Preferences** for a more detailed discussion of each menu item.

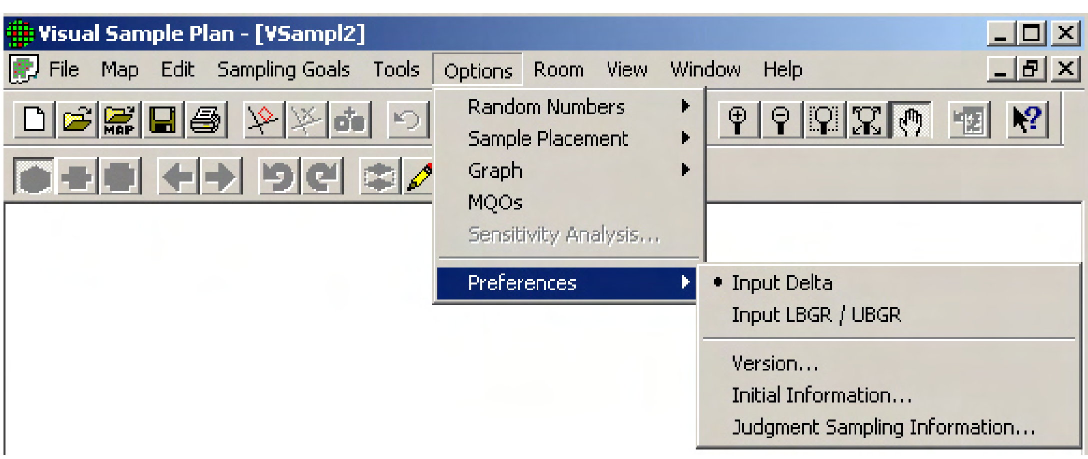


Figure 5.21. Preferences Available in VSP

Table 5.1. Preferences Menu Items

Input Delta	Allows the input of Delta in design dialog boxes
Input LBGR / UBGR	Allows the input of LBGR / UBGR in design dialog boxes.
Version	Changes the sub-version of VSP (which eliminates some of the sampling design choices)
Initial Information	Displays the initial information associated with the chosen sub-version of VSP.
Judgment Sampling Information	Displays informational dialog when judgment sampling is used.

5.3 View Menu

The View Menu offers the user options for how VSP displays information. Table 5.2 gives a brief description of each option. Consult VSP **Help > Help Topics > Menus > View menu** for a more detail discussion of each menu item. Many of these items have been discussed previously in this manual and will be mentioned only briefly here.

Table 5.2. View Menu Items

Main Toolbar	Shows or hides the main toolbar
Map Drawing Toolbar	Shows or hides the toolbar used for drawing on maps.
Ranked Set Toolbar	Shows or hides the toolbar used for ranked set sampling
Room Toolbar	Shows or hides the toolbar used for room manipulation
Status Bar	Shows or hides the status bar.
Labels	Shows or hides the sample labels on the map. Any combination of Labels, Coordinates, Local Coordinates and Values can be displayed.
Background Picture	Shows or hides the background picture.
Transparent Sample Area	Allow background picture to be seen behind sample areas.
Largest Unsampled Spots	Shows or hides the largest unsampled spots.
All Grid Cells	Shows or hides all grid cells used for adaptive cluster sampling
Leading Edge	Shows only the leading edge of an open-type sample area
Map Scale	Shows or hides the coordinate scale on the map.
Map Legend	Shows or hides the map size legend.
Color Legend	Shows or hides the color legend.
Transect Corners	Shows the coordinates at the corners of transects
Kriged Data	Showw or hidew the Kriged results from "Geostatistical mapping of anomaly density" or "Geostatistical Analysis".
Anomalies	Shows or hides the anomaly markers on the map for UXO designs.
Transects	Show or hides the transects on the map for UXO designs.
Target Flags	Shows or hides the target flags on the map for UXO designs.
Room North Arrow	Shows or hides the north arrow in the room view.
Room Perspective Ceiling	Shows or hides the ceiling in the perspective room view.
Map	Change current project view to map view.
Graph	Change current project view to graph view.
Report	Change current project view to report view.
Coordinates	Change current project view to coordinate view.
Room	Change current project view to room view.
3D	Changes the current window to a 3D view.
Zoom In	Increase the map view size.

Zoom Out	Decrease the map view size.
Zoom Max	Change map view size to fit window
Zoom Window	Increase map view size to selected area.
Pan	Move the visible portion of the map.
Rotate	Rotates or tilts the map in the 3D view window.

5.4 The Cost Tab: Setting Up Sampling Costs – Inputs for the General Screen

VSP allows users to enter sampling costs so that the total cost of a sampling program is available. Once a sampling design is selected and the DQO inputs have been entered into one of the dialog boxes, click on the **Costs** tab to enter costs. A sample **Costs** screen is shown in Figure 5.22. The inputs for this example were entered in the Dialog Box shown in Figure 5.13.

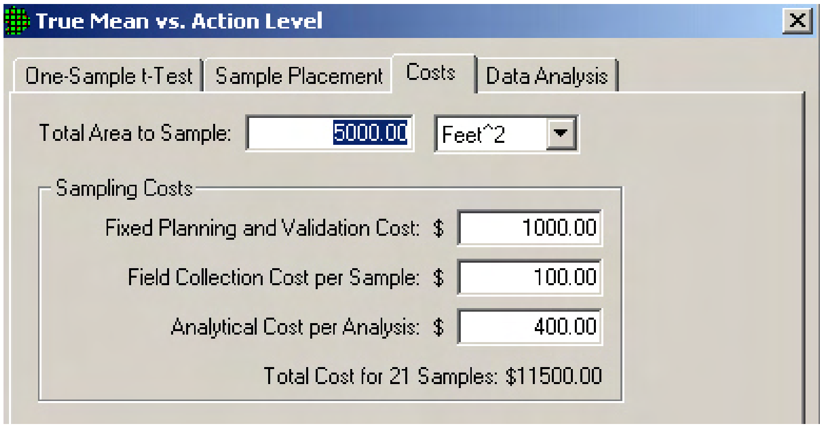


Figure 5.22. Screen for Entering Sampling Costs for a Sampling Design – Accessed through the Cost Tab

VSP enables you to break down costs into the following categories:

- *fixed planning and validation costs* - This is the fixed cost that is incurred, regardless of how many samples are taken. Examples of fixed costs are the cost to mobilize a sampling crew and get the equipment into the field.

- *field collection cost per sample* - This is the per-sample **field collection cost.** Examples of per-unit field costs are the costs paid to technicians to collect the sample and package and transport it.

- *analytical cost per analysis* - This is the cost to analyze a specimen or a sample. As discussed in Section 5.4, you can specify how many repeated analyses you want taken per sample or specimen.

VSP calculates a total cost for the design specified, shown here as $11,500. Total cost is the sum of the fixed cost, shown here as $1,000, plus per-sample field collection cost of $100, plus analytical cost per analysis of $400, multiplied by the number of samples, 21. No duplicate analyses were specified, so the total per-unit cost is $500. Thus, the total sampling cost is $1000 + 21 x $500 = $11,500.

The hot spot sampling goal has some unique cost features. First, total costs are displayed in one of the tables in the **Report View**. Second, you can specify a cost as a design criteria and VSP will calculate the number of samples to meet that goal (see Figure 3.29). This is done by selecting from the main menu **Sampling Goal > Locating a Hot Spot > Assume no false negative errors.**

5.5 Multiple Areas to be Sampled

VSP allows the user to select multiple areas as sampling areas. All the examples shown so far involved a single Sample Area. When multiple areas are selected, VSP allocates the samples to the areas in proportion to the area of the respective individual sample areas. For example, if one area is twice as large as the other sample area, it will receive twice as many sample points. This is shown in Figure 5.23.

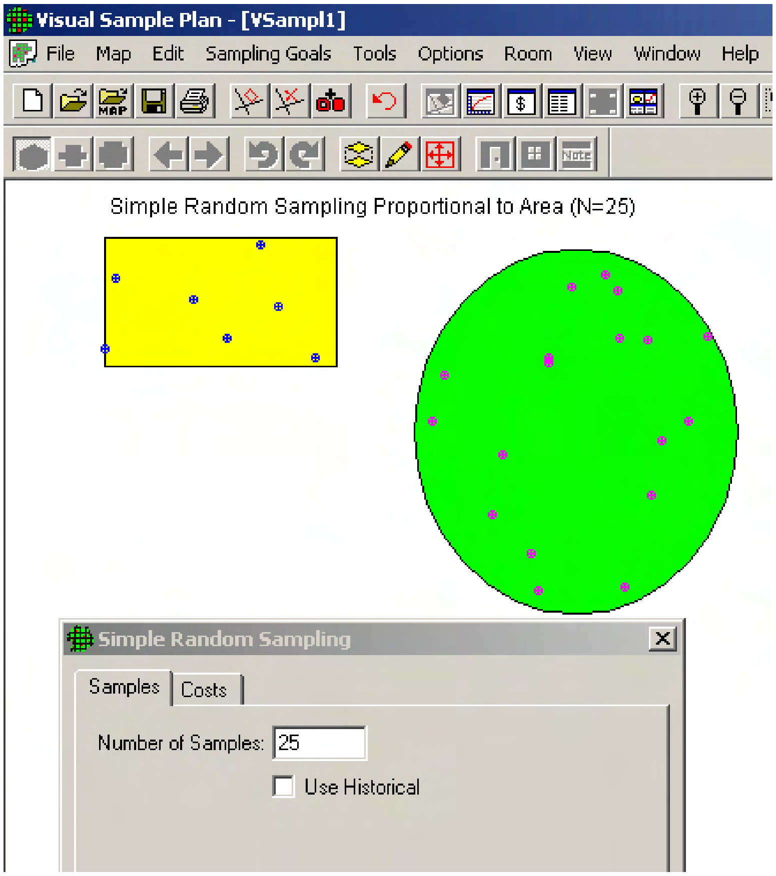


Figure 5.23. Proportional Allocation of Samples to Multiple Sample Areas

In Figure 5.23, we show two sample areas -- a rectangle and a circle. We next assume that a sampling-design algorithm not currently in VSP called for $n = 25$ samples. Using option **Sampling Goals > Non-statistical sampling approach > Predetermined number of samples > Ordinary sampling,** VSP allocated 7 of the 25 requested samples to the rectangle and 18 to the circle. This is because the circle covers an area approximately three times larger than the rectangle.

Note that when multiple sample areas are drawn on a Map, you can select or deselect sample areas using Main Menu option **Edit** > **Sample Areas** > **Select/Deselect Sample Areas.** Alternatively, you can select or deselect a sample area by clicking on it with the mouse.

The **Change Color** option can be used to change a sample area's color. First, select those sample areas to be given a new color. Then use the **Edit** > **Sample Areas** > **Change Color** sequence and choose the new color for the currently selected sample areas.

Note that when multiple sample areas are selected, VSP-derived sampling requirements assume that the decision criteria and summary statistic of interest (mean, median) apply to the combined sample areas and not to the individual areas.

5.6 Data Analysis

For some sampling goals, VSP allows the user to input the results of a sampling effort and obtain certain basic analyses of the data, including summary statistics, plots of the data, and results of statistical tests performed on the data. VSP provides a statement of the conclusion(s) that can be drawn based on results of the statistical tests. Only selected tests appropriate for the design in question are displayed. The tests included in VSP are standard statistical tests and are included in VSP for the convenience for the user so a separate software package for analyzing results in not needed. The tests and calculations used in VSP have been verified. This verification, along with an extensive discussion of the methods used in VSP, can be found in PNNL reports: *Technical Documentation and Verification for the Buildings Module in the Visual Sample Plan (VSP) Software*, PNNL –15202, June, 2005, and *Version 2.0 Visual Sample Plan (VSP): Models and Code Verification*, PNNL-13991, August 2002. If the user wants to perform more complex tests and analyses, a commercial statistical software package, or freeware such as EPA's ProUCL (ProUCL Version 3.0 User Guide April 2004, available for download from http://www.epa.gov/nerlesd1/tsc/tsc.htm) should be consulted.

Figure 5.24 shows a Dialog Box that appears when the user selects the **Data Analysis** tab for **Compare Average to Fixed Threshold > Assume data will be normally distributed > Ordinary Sampling.**

In Figure 5.24, we see five options: **Data Entry, Summary Statistics, Tests, Plots, and Analytes**. **Data Entry** is a user input screen for inputting data values. **Summary Statistics** displays VSP calculations, shown in red, of selected summary statistics of the data input in Data Entry. The **Tests** tab displays the results of computations done within VSP to execute various *tests* and make various *calculations*. The *tests* are of two types:

- Tests of the assumptions underlying the statistical tests (e.g., the normality assumption for the One Sample t test), and

- Statistical tests to test the Null vs. Alternative Hypothesis for the sampling goal selected

Calculations made by VSP are

- Upper Confidence Limit (parametric and non-parametric) on the Mean and on Percentiles, and
- A count of the number of sample points or grid locations that exceed the Action Level.

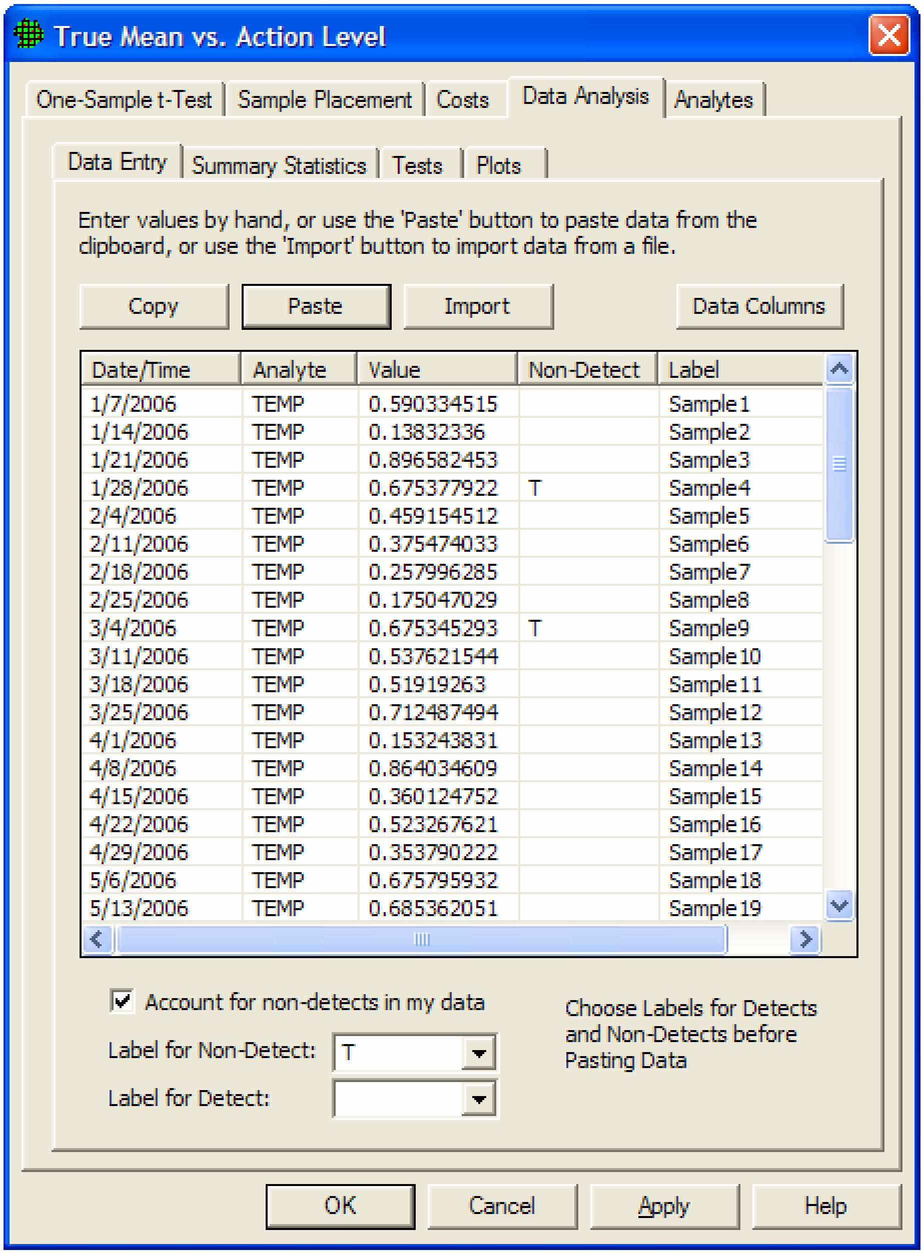


Figure 5.24 Data Analysis Tab for the One-Sample t-Test, Data Entry Dialog Box

Output from VSP, and conclusions that VSP determines can be drawn based on the *test* results and *calculations*, are shown in red on the **Tests** screen. The **Plots** tab shows VSP-generated graphical displays of the data. The **Analytes** tab shows a table of the different Analytes available and allows for addition of new analytes.

Checking the **Account for non-detects in my data** box allows the option of designating some Values as non-detects. This implies the true Value is somewhere between 0 and the Value shown. In Figure 5.24, data entries with non-detects are identified by a "T" and detects are identified by a blank cell in the **Non-Detect** column. Different options for differentiating non-detects from detects are available in the **Label**

for Non-Detect and **Label for Detect** drop downs. The methods used for other data analysis functions will sometimes change due to the presence of non-detects.

Not all sampling designs in VSP have the Data Analysis tab – either because analyzing sampling results is not a part of the sampling goal, or because VSP sponsors have not requested the VSP data analysis functionality. For example, **Locating a Hot Spot** does not have a Data Analysis tab because the result of sampling is whether or not there has been a hit at any sampling location, which this doesn't require data analysis. Similarly, **Estimate the Mean > Can assume will be normally distributed > Adaptive Cluster Sampling** does not have a Data Analysis tab because the sampling goal is interactive and does not require a statistical test. Some sampling designs, like Collaborative Sampling, have a **Data** tab for inputting sample results, but not a Data Analysis tab.

For brevity, the Data Analysis for only a few sampling designs will be discussed below. Consult the **Help** function for individual designs for further information.

5.6.1 Data Entry

Data can be entered into VSP in one of two ways: manually or "cut and paste" from another file. To manually enter values, click the mouse in the first line in the input box under **Value**, enter the numeric value for a sampling point, hit **Enter** or **Tab**, and move to the next line for more input. If the data are in another software package such as Excel, use the Windows clipboard to copy the data, then hit **Paste** to get the data into VSP. The data to be pasted into VSP must be one entry per line in the originating source. You can manually add more input values to a set of Pasted values by clicking on the last data value in the input box, hit Enter or Tab, and start entering more data values on the next empty line. You must hit the **OK** or **Apply** button at the bottom of the screen to save your values in a Project file. Figure 5.24 shows 60 values pasted into VSP from an Excel spreadsheet.

5.6.2 Summary Statistics

Figure 5.25 shows summaries of the data input under Data Entry. The values for the summary statistics are shown in red. The summary statistics, when shown, are the same for all sampling designs.

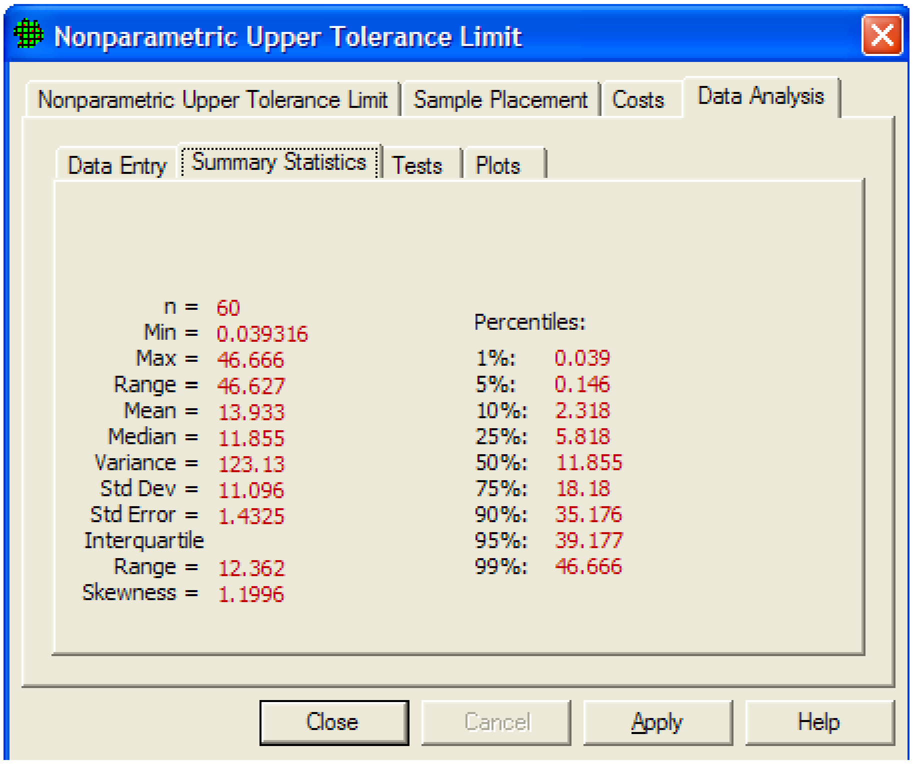


Figure 5.25 Summary Statistics for Data Values Entered on Data Entry Screen

5.6.3 Tests

The *tests* and *calculations* required by VSP to draw conclusions based on the data input under Data Entry are the core of VSP's data analysis. After telling the VSP user how many samples to take and where to take them, the next most important function of VSP is to tell the user what conclusions can be drawn based on the data. But prior to drawing conclusions, VSP must make sure the assumptions on which the *tests* and *calculations* rely are valid.

The tests in VSP vary by the Sampling Goal selected, and the assumptions made. The tests shown in the screen captures below are an example of the types of tests contained in VSP. Not all data analysis options are shown below.

5.6.3.1 Tests for Sampling Goal: **Compare Average to Fixed Threshold > Assume data will be normally distributed > Ordinary Sampling**

The One-Sample t test is used to test the null hypothesis **True Mean >= Action Level**. However, the t test relies on the assumption that the data are normally distributed. So the first test VSP performs is to test the normality assumption. Two tests are available in VSP for testing for normality:

- Shapiro-Wilk Test (also called W test) when the number of data points do not exceed 50, and
- Lilliefors Test when the number of data points are greater then 50.

Our sample size was n=60, so the Lilliefors test was used. In Figure 5.26a we see the Lilliefors test results indicate we cannot assume normality (i.e., test statistic of .12961 > critical value of .11438 so we reject the assumption of normality).

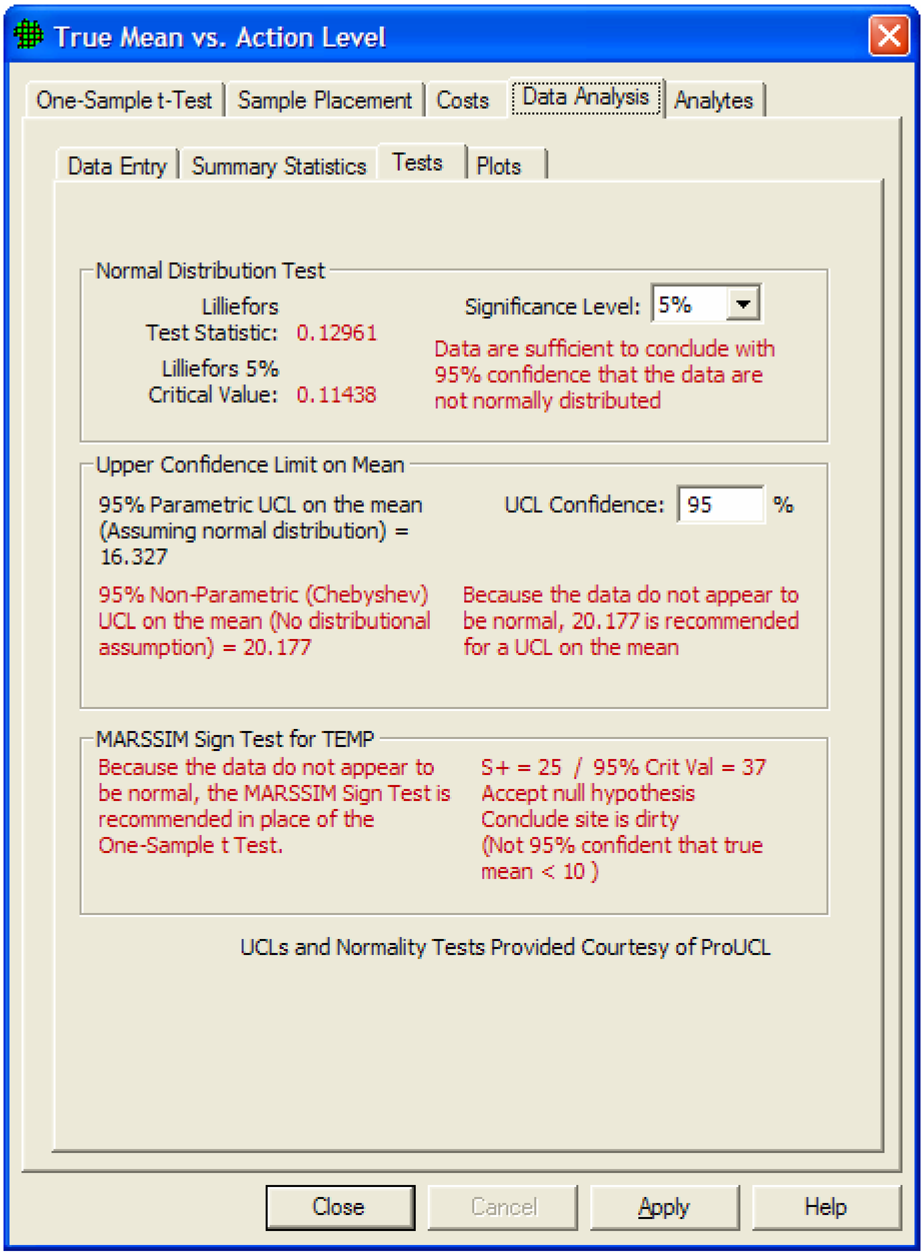


Figure 5.26a Tests for Comparing the True Mean vs. Action Level

With the normality assumption rejected, we now know we must use a non-parametric test to test the null hypothesis that the **True Mean >=Action Level**. The test we use is to compare the Non-Parametric UCL on the mean to the action level. We see that the Non-Parametric UCL on the mean is **20.177** which is greater than the Action Level of **10**, so we cannot reject the null hypothesis, and we can **conclude the site is dirty.**

5.6.3.2 Tests for Sampling Goal: **Sampling within a Building > Compare measurements to threshold > Quantitative measurements > Upper tolerance limit > Unknown Distribution**

In Figure 5.26b we see the tests VSP executes in order to make confidence statements on a percentile of the population. For example, the goal may be to be able to state with 95% confidence that at least 95% of the values in a population are less than the action level, and therefore the decision unit is contaminated (see Fig 3.47 for a description of the problem). The test is to calculate the Upper Tolerance Limit on the 95th percentile of a population and compare it to the action level. Note: A one-sided upper tolerance limit on the Pth percentile is identical to a one-sided upper confidence limit on a Pth percentile of the population. The maximum value of a data set is the non-parametric UTL.

In this example, since the sample size was n=60, the Lilliefors test was used. We see that the Lilliefors test rejects that the data are normal, so VSP recommends comparing the nonparametric UTL to the Action Level for deciding whether the unit is contaminated. Since the nonparametric UTL of 46.666 is greater than the action level of 10, we conclude the site is dirty (i.e., less than 95% of the population is less than the action level of 10). VSP also calculates a parametric UTL of 36.371 but recommends not using it in the test.

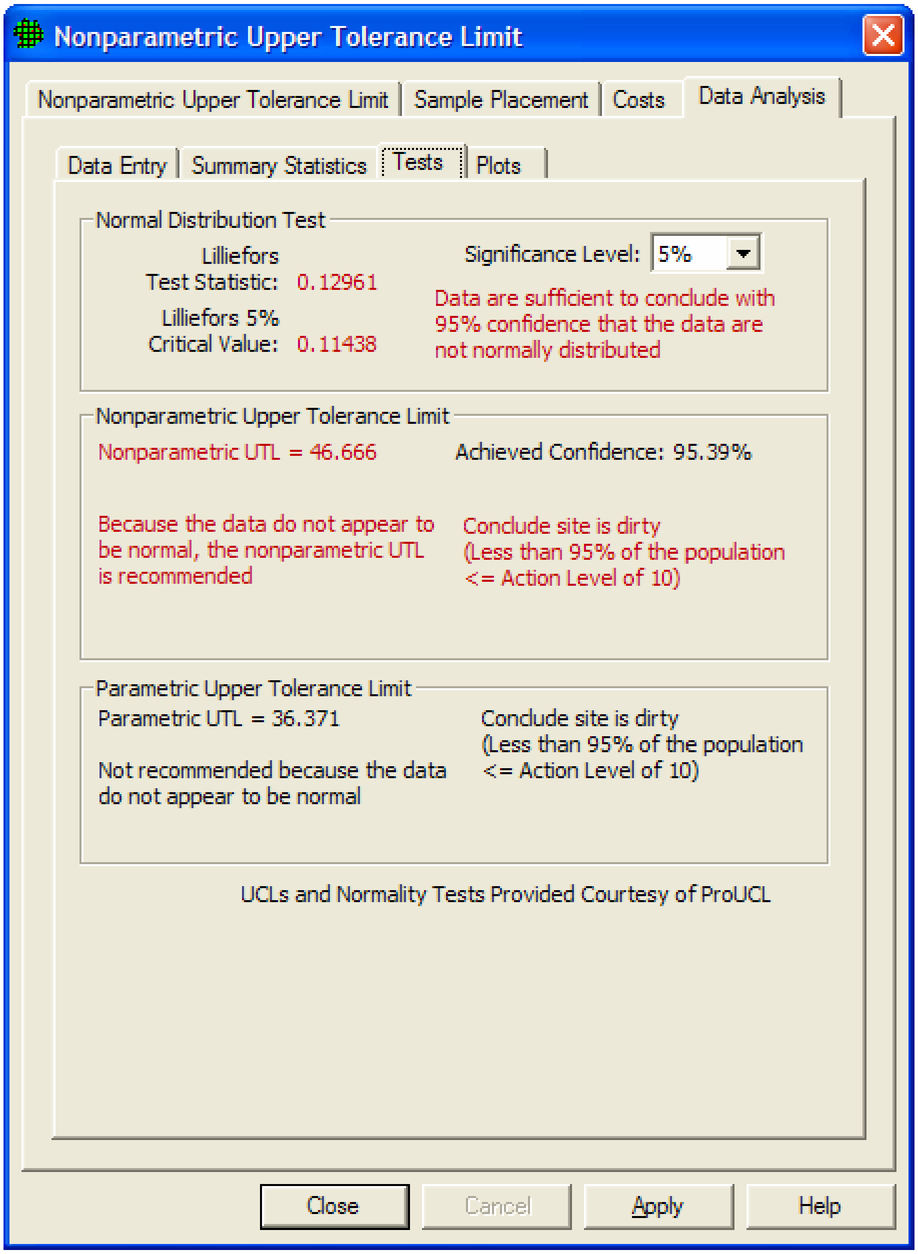


Figure 5.26b Tests for Comparing the True Mean vs. Action Level

5.6.4 Plots

VSP provides three graphical summaries of the data: histogram, box-and-whiskers plot, and quantile-quantile plot (also called the Q-Q plot, or the probability plot). The pull down menu is used to select one of the three plots. The graphical displays provide information on the spread of the data, and can also be used to give a visual assessment of the normality assumption.

5.6.4.1 Histogram

Figure 5.27 shows a histogram of the data. The red line shows the shape of the histogram if the data were normally distributed. Consistent with the results of the Lilliefors Test, the data do not appear to be normally distributed.

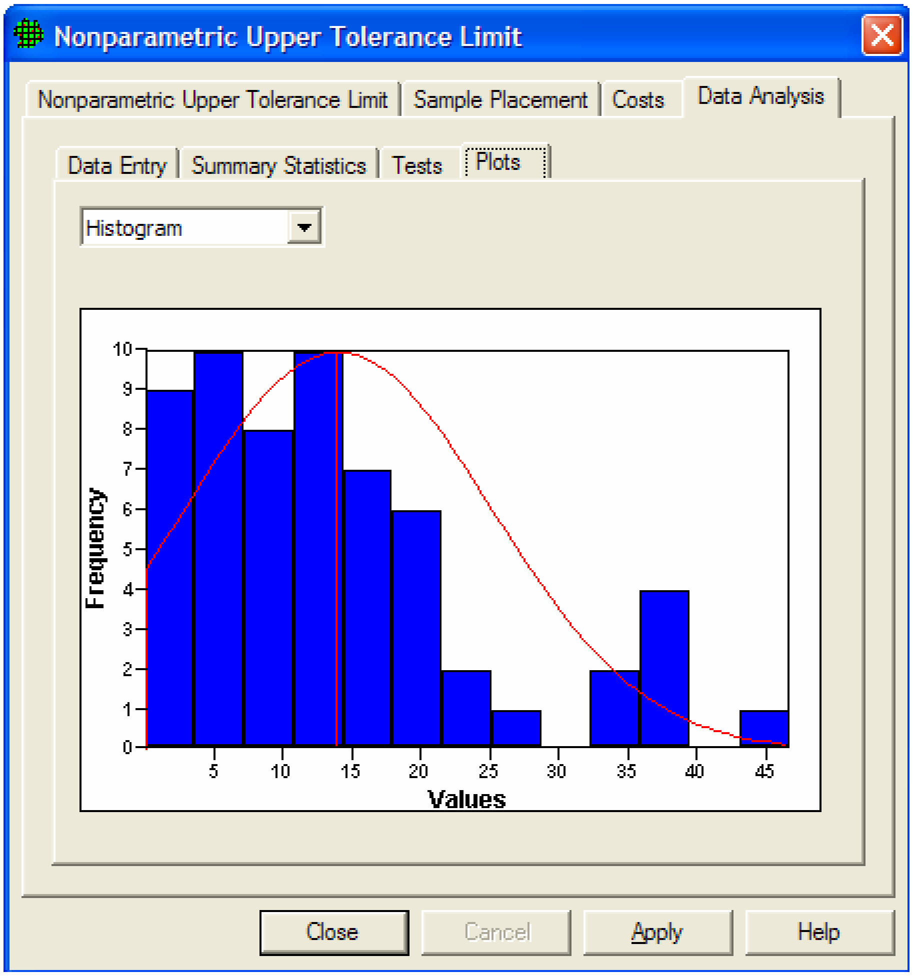


Figure 5.27 Histogram of the data

5.6.4.2 Box-and-Whiskers Plot

Figure 5.28 shows a Box-and-Whiskers plot of the data. The Box-and-Whiskers plot is composed of a central "box" divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the data (i.e., the 50th percentile). The two ends of the box represent the 25th and 75th percentiles of the data, also called the lower and upper quartiles of the data set. The sample mean is shown as a red "+". The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile – lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually. If the data are normally distributed, the box and whiskers appear symmetrical, with the median midway between the ends of the box (i.e., the 25th and 75th percentiles), and the mean is equal to the median. The plot in Figure 5.28 is not symmetrical, consistent with the non-normality conclusion discussed above.

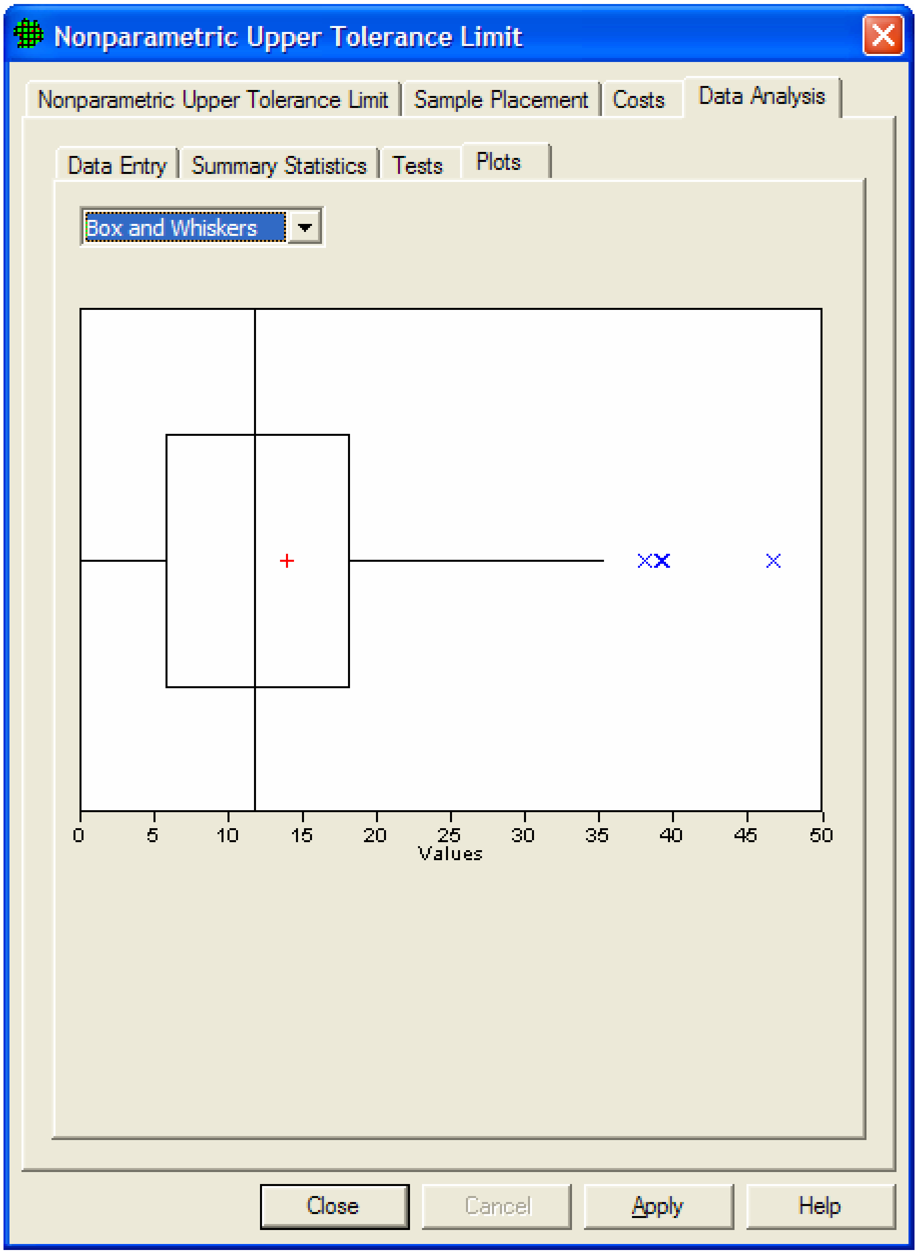


Figure 5.28 Box-and-Whiskers Plot

5.6.4.3 Quantile-Quantile (Q-Q) Plot

The Q-Q plot graphs the quantiles of a set of data against the quantiles of a specific distribution. We show here the normal distribution Q-Q plot. The red line shows quantiles of a normal distribution plotted against quantiles of a normal distribution – i.e., a straight line. If the graph of data plotted against quantiles of a normal distribution (shown as blue x's) fall along the linear line, the data appear to be normally distributed. In Figure 5.29 the tails of the data deviate from the red line, indicating the data are not normally distributed.

For more information on these three plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

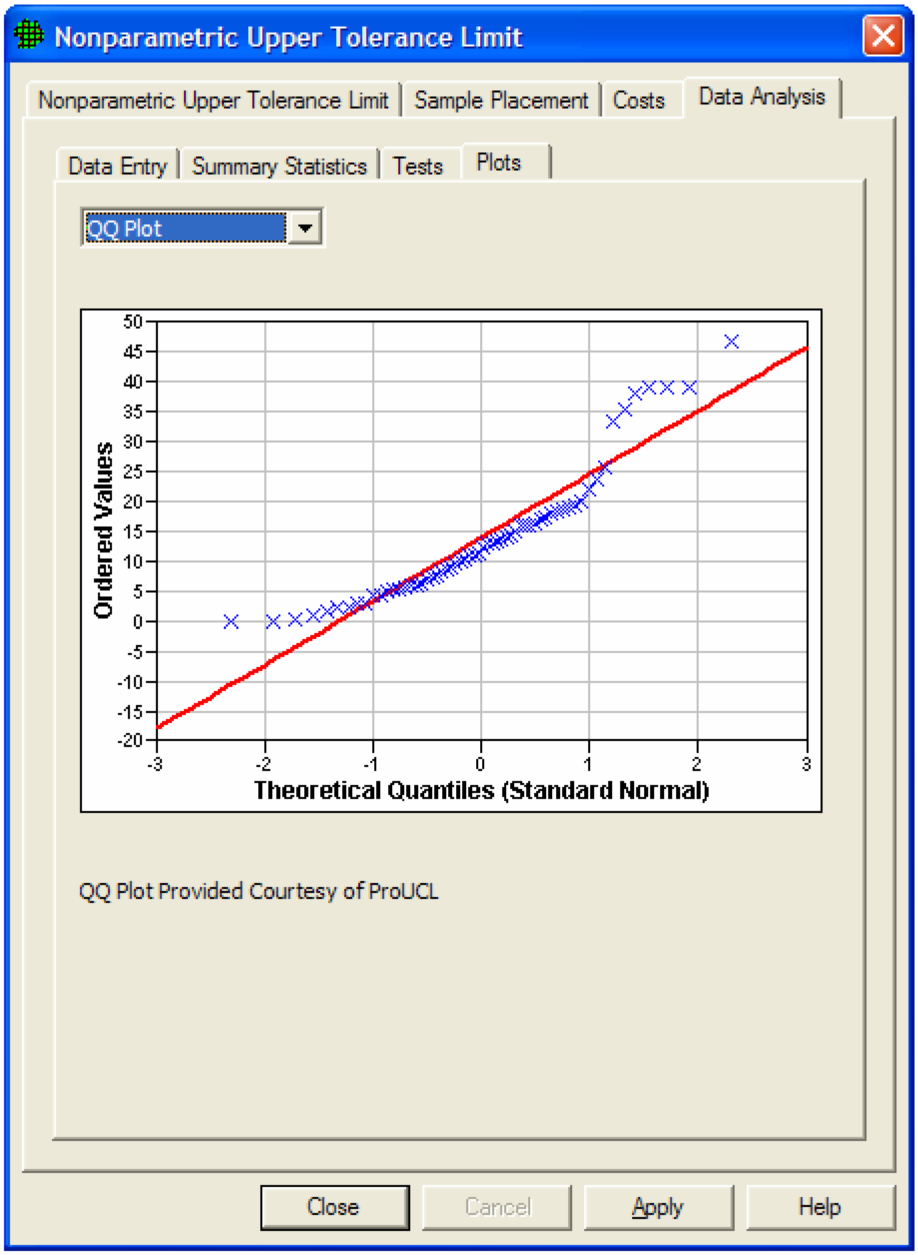


Figure 5.29 Quantile-Quantile (or Q-Q) Plot

5.6.5 Analytes

Some tools in VSP also have an “Analtyes” tab that controls the properties of the analytes used in the sample design and data analysis. The Analyte page contains a data grid with **Analyte**, **Action Limit**, and **Units** columns. The Analyte is the name of the chemical or variable, and each analyte collected should be listed. The Action Limit is the action level for this analyte. This value is shared with the action level on the main design page. The Units are the units associated with the analysis results. Examples: (ppm, ppb, mg/Kg, pCi/g, etc.)

6.0 Room Features in VSP

VSP has a complete room supporting infrastructure, including sampling locations in 3 dimensions and a local coordinate system. Under this system, a room in VSP is any Sample Area that has a height greater than zero. The floor, walls and ceiling can be viewed in the **Room View**. Objects like doors and windows can be placed in a room. Additional flat surfaces, called **surface overlays**, can also be placed in the room to represent portions of a surface that need to be distinguished from the overall surface. Surface overlays can also be elevated to represent the top surface of furniture. Samples can be placed on the walls, ceiling, and surface overlays of a room as well as on the floor and on doors and windows. Samples are placed on all selected rooms. To display the Room View, select **View > Room** from the main menu or click on the **Room View** tool button on the main toolbar. Many of the VSP room features are described in Section 2.5.1 Drawing a Room.

Some of the menu commands discussed in this chapter also have tool button shortcuts available on the **Room Toolbar**. To activate the Room Toolbar, select **View > Room Toolbar** on the main menu.

6.1 Room Creation and Manipulation

6.1.1 Creating a Room from a Sample Area

Since a room in VSP is simply a sample area that has had its height set greater than zero, the simplest way to create a room is to create a sample area and set its height to something like 8 feet. To set the height of a room, right-click on the sample area on the map to display the Sample Area Information dialog box (see Figure 6.1). The room height is one of the parameters that can be modified in this information dialog box. The **Room > Set Room Height** menu command (or **Set Height** tool button) displays a dialog that sets the height of all selected sample areas when the Map View is active, or sets the height of only the current room when the Room View is active. (See Section 6.2.1 for a definition of current room.)

The Sample Area Information dialog also allows you to include or exclude the floor and the ceiling from a room. These are included by default. If these surfaces are excluded they will not receive sample points from any sampling design and they will not be displayed in the Room view.

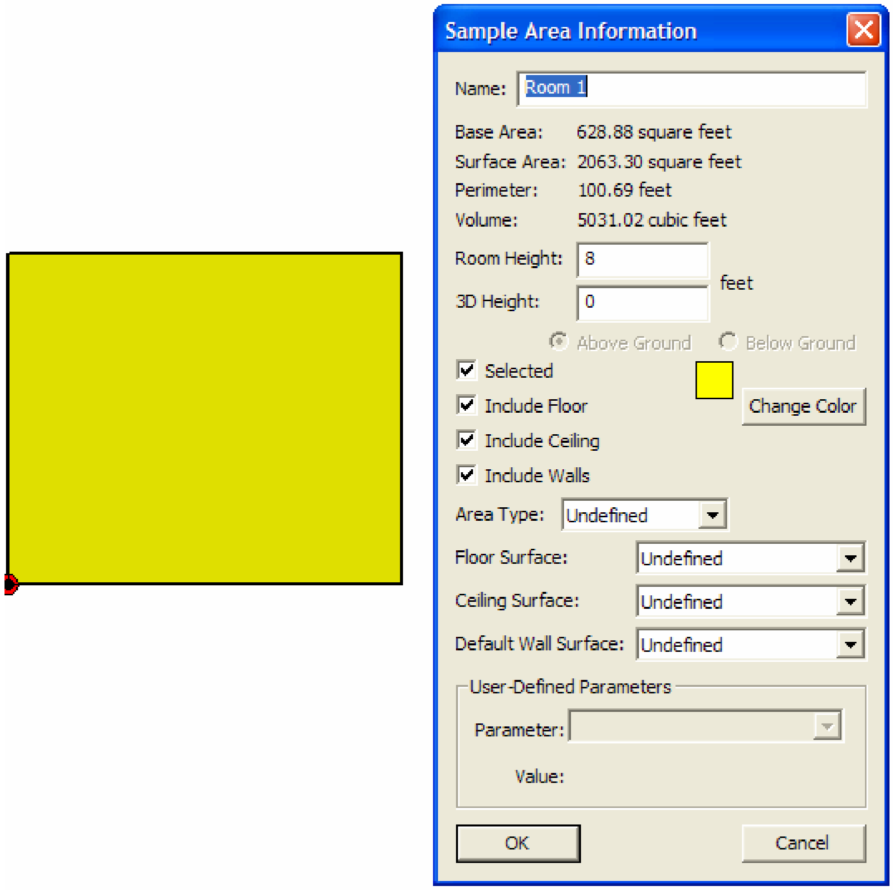


Figure 6. 1 Sample Area Information Dialog

6.1.2 Drawing a Room

The **Room** > **Draw** menu command (or the Draw Room tool button) allows you to draw a room on the map. Drawing a room is similar to drawing a rectangle, except that it automatically sets the wall height for you. Define one corner of the floor rectangle by clicking on the map with the left mouse button or by entering the coordinates on the keyboard (e.g., 100,200<Enter>). Then enter the opposite corner with the mouse or keyboard. Holding the Ctrl key while clicking on the map limits the floor rectangle to a square.

An alternate method of defining a room is to enter the length, width, and height on the keyboard (Length x Width x Height <Enter>). If the room is defined this way, then one corner is placed at the origin (0,0).

6.1.3 Room Delineation Method

If you have a building floor-plan map (such as a .dxf file from a CAD system), the **room delineation** method is usually the fastest and easiest way to create rooms in VSP. Choosing **Room > Delineate Rooms** from the menu (or clicking the Delineate Rooms tool button) toggles the room delineation mode on or off. The room delineation mode allows you to create rooms with right angles inside existing map shapes. This mode is for use in the map view. If a room contains some walls that are not at right angles to other walls, those rooms will need to be created by the first method outlined in section 6.1.1.

While in this mode, left-clicking with the mouse creates a red rectangle. The red rectangle is framed by moving up, down, left and right from the point clicked and stopping at the first line encountered in that direction. Several red rectangles may be needed to fill up the space inside an irregular shaped room on the map.

After the room is filled with adjoining red rectangles, right-click with the mouse to combine all the rectangles into a room. If there are disjoint red rectangles, each group of red rectangles becomes a separate room. Figure 6.2a and 6.2b illustrates the delineation method in action.

If the desired room is a simple rectangle, right-click with the mouse to create the rectangle and convert it to a room in a single step. Remember the red and black bulls-eye in the bottom left-hand corner of the room in Figure 6.2b marks the location of the Room Origin for local coordinates (see Section 6.4.2).

6.1.4 Room Manipulation

The room can be modified in the map view by inserting a point into a wall and then moving the wall section. To insert a new point into a wall, use the **Map > Insert** Point menu command. To move a wall section, select the wall section by holding down the Shift key while clicking on the center of a wall segment. Once selected, the wall segment can be dragged with the mouse. Hold the Ctrl key down while dragging to the wall aligned at right angles. Figure 6.3 illustrates a new point inserted on the right side of a room, the segment selected, and the segment being dragged outward.

You can also set the exact length of a selected wall segment by right-clicking on it. This displays a dialog that allows you to change the length of the segment. Figure 6.4 illustrates a segment length being changed with the dialog.

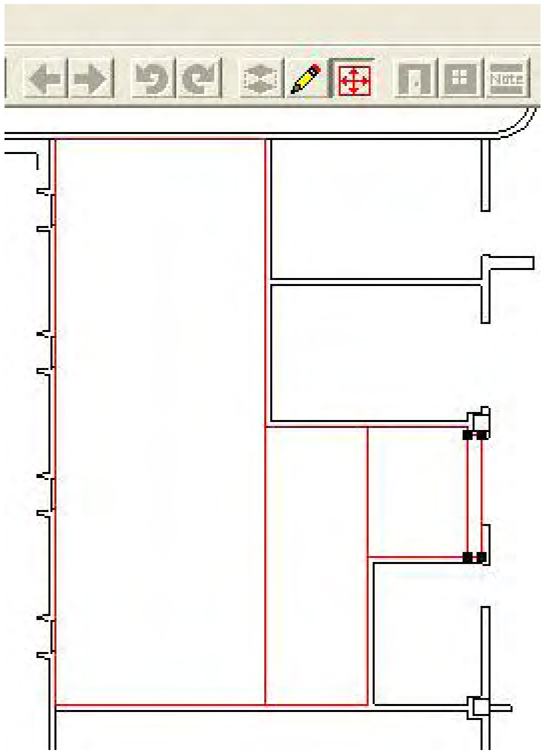


Figure 6.1a. Room Delineation Mode

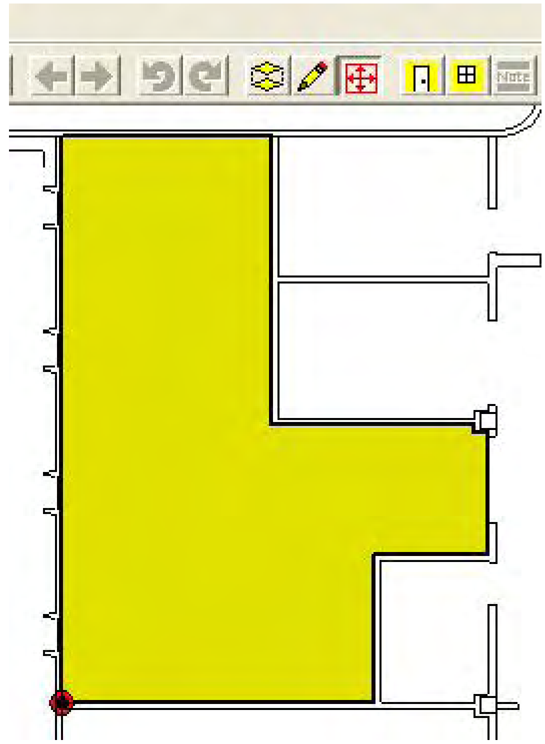


Figure 6.2b. Room Delineation Mode

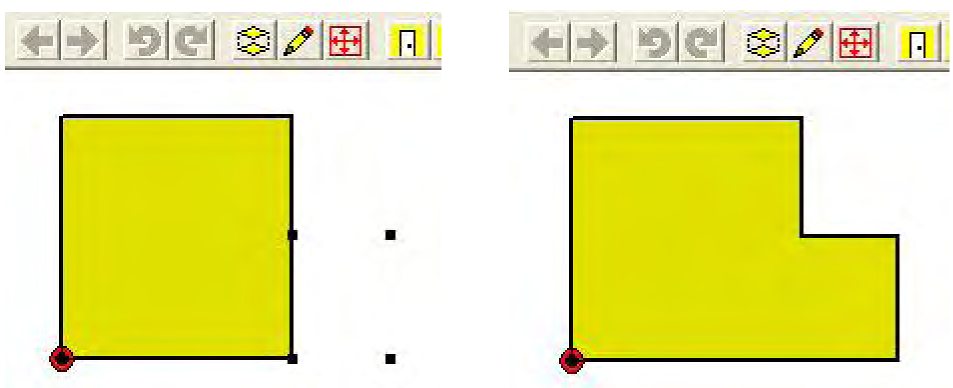
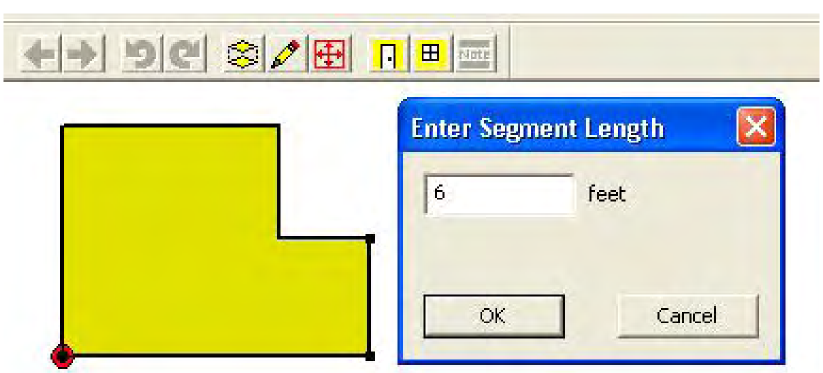


Figure 6.3. Room Manipulation



The On-line Help functions provide more detailed instructions on room manipulation.

Figure 6.4. Changing Segment Length

6.2 Room Display Options

6.2.1 Current Room

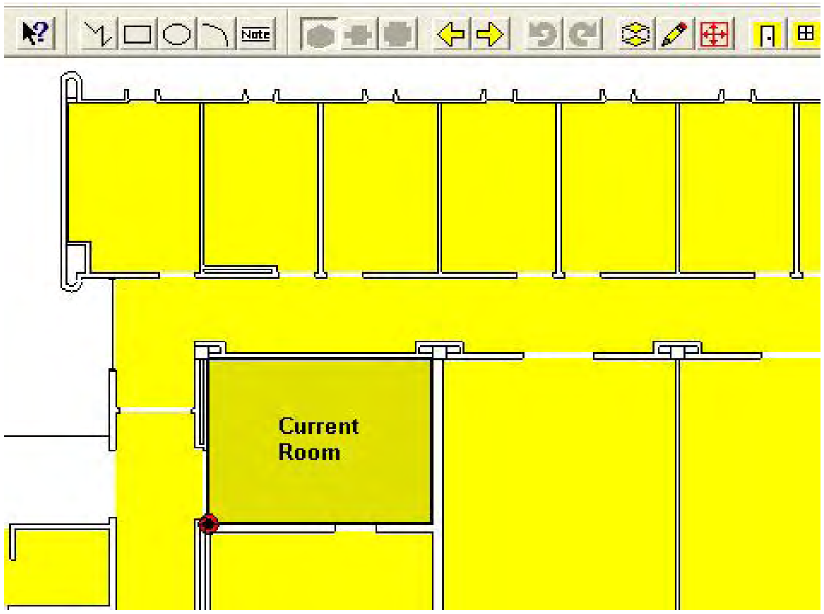


Figure 6.5. Current Room

When one or more rooms are selected on a map, exactly one of the rooms is the current room. The current room is the one that is displayed in the Room View. The current room is also indicated on the map by a thick black border and a darker shade. The last room to be created, selected, or viewed with the Sample Information dialog becomes the current room. Using the **Room > Next Room** or **Room > Previous Room** menu commands scrolls through the list of selected rooms. Each of these commands also has a tool button. Figure 6.5 shows the current room in the Map View. Remember that samples are placed on all *selected sample areas/rooms*, not just the current room. If you want to place objects within a room, such as a door or a window, they can only be placed on the current room.

6.2.2 Room View Types

VSP provides 3 different room view types: perspective, wall-strip and splayed. These view types can be selected using the menu commands:

Room > **Perspective Room** (or **Perspective Room** tool button)
Room > **Room with Wall Strip** (or **Wall Strip Room** tool button)
Room > **Splayed Room** (or **Splayed Room** tool button)

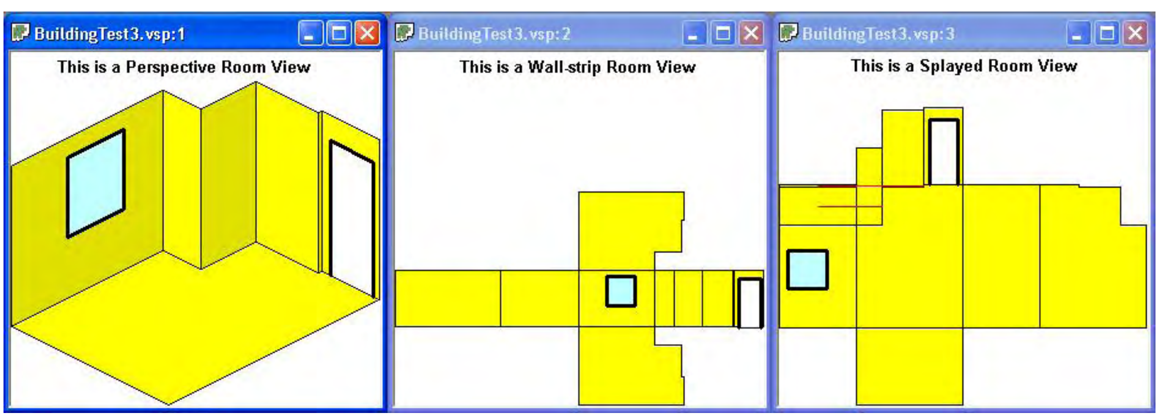


Figure 6.6. Room View Types

6.2.2.1 Perspective Room

The perspective room view shows the room as a 3-dimension semi-perspective view. Inside wall surfaces that are facing you are displayed; inside wall surfaces that are facing away are not displayed. The floor is shown tilted down and the ceiling (if included) is shown tilted up. The wall sections are shown attached to the floor surface. (If the floor is excluded and the ceiling is included, then the wall sections are shown attached to the ceiling surface.)

The **Room** > **Rotate Room Left** and **Room** > **Rotate Room Right** menu commands (or the Rotate Left and Rotate Right tool buttons) rotate the room by 90 degrees, to allow viewing from a different perspective. This does not change the coordinates of the room or any object associated with the room, such as sample locations.

6.2.2.2 Wall-Strip Room

The wall strip room view shows a floor (if included), a mirror-image ceiling (if included), and a strip of wall sections laid edge to edge. The floor and ceiling surfaces are shown attached to the proper wall section.

The **Room** > **Rotate Room Left** and **Room** > **Rotate Room Right** menu commands (or the Rotate Left and Rotate Right tool buttons) rotate the room by 90 degrees, to allow viewing the floor and ceiling from different angles. This does not change the coordinates of the room or any object associated with the room, such as sample locations.

6.2.2.3 Splayed Room

The splayed room view shows a floor, a mirror-image ceiling, and individual wall sections laid outward from the floor. The wall sections are originally laid down so that they do not overlap. If the wall section is not shown attached to the floor, a red line shows where it should be attached.

To move a wall section to a new location on the display, simply click and drag with the mouse. Right-click with the mouse on a wall section to move it back to its attached location. Moving a wall section on the display does not change the coordinates of the room or any object associated with the room, such as sample locations.

6.2.3 Room North Arrow

By default, VSP places a north arrow on the room floor and ceiling surface. Figure 6.7 shows the north arrows on the floor and ceiling. Use the **View** > **Room North Arrow** command to show or hide the north arrow. The location of the north arrow can be changed by grabbing the center of the north arrow with the mouse and dragging it. (The center to grab is between the N and the arrow.)

VSP assumes by default that north is the top of your map. If this is not the case, select the **Map** > **Map Settings** menu command. Change the North Offset in the Map Extents dialog box to correct the direction of north on your map.

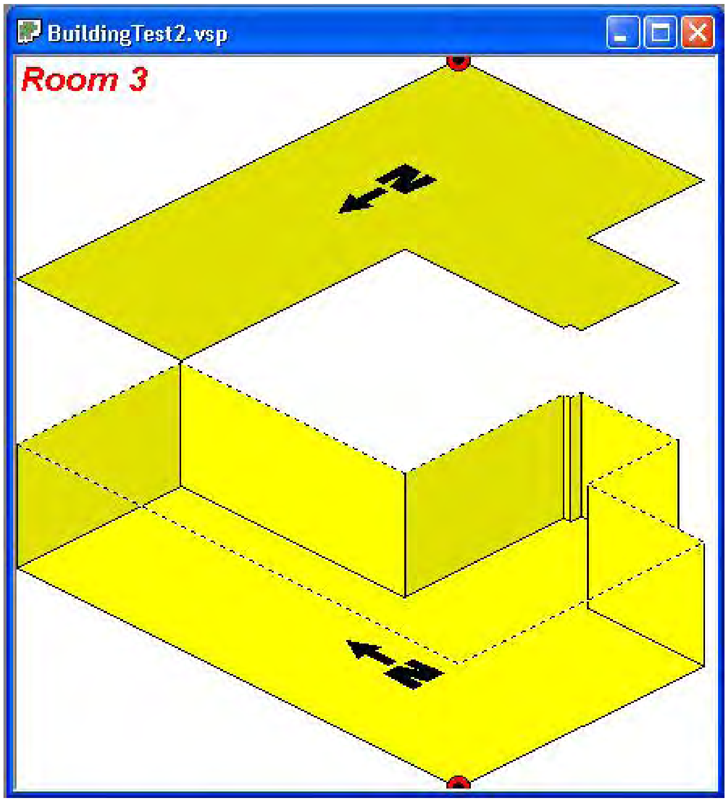


Figure 6.7. Room North Arrows

6.2.4 Perspective Ceiling

If you prefer not to see the ceiling in the perspective view, use the **View** > **Room Perspective Ceiling** command to hide the ceiling.

6.3 Room Objects

Doors, Windows, Annotations, and Surface Overlays can be inserted into a room. Figure 6.8 shows a room with a door, window, and annotation.

6.3.1 Doors

To insert a door object into the current room, use the **Room** > **Insert Door** menu command (or **Insert Door** tool button). This command can be used in the Map View or the Room View.

After selecting this command, click on one edge of the door and then on the other edge of the door. On the Map View, the coordinates can also be entered on the keyboard. Hold the shift key while clicking to attach the door to the nearest point on the map. Both edges of the window must be on the same wall section. Note that doors are inserted into the current room (see section 6.2.1).

Doors can be moved, resized or deleted by using the **Object Information** dialog which is access by right clicking on the door. This dialog also allows you to change the door sub-type: Open Door (sample locations will be excluded from the door surface) or Fixed Door (sample locations can be included on the door surface). Figure 6.9 shows the Object Information dialog for a door.

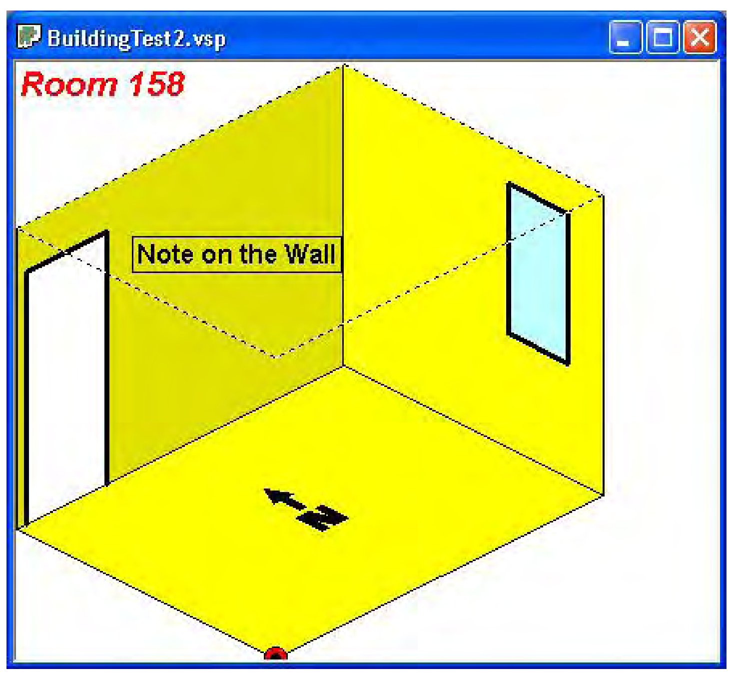


Figure 6.8. Room Objects

6.3.2 Windows

To insert a window object into the current room, use the **Room** > **Insert Window** menu command (or **Insert Window** tool button). This command can be used in the Map View or the Room View.

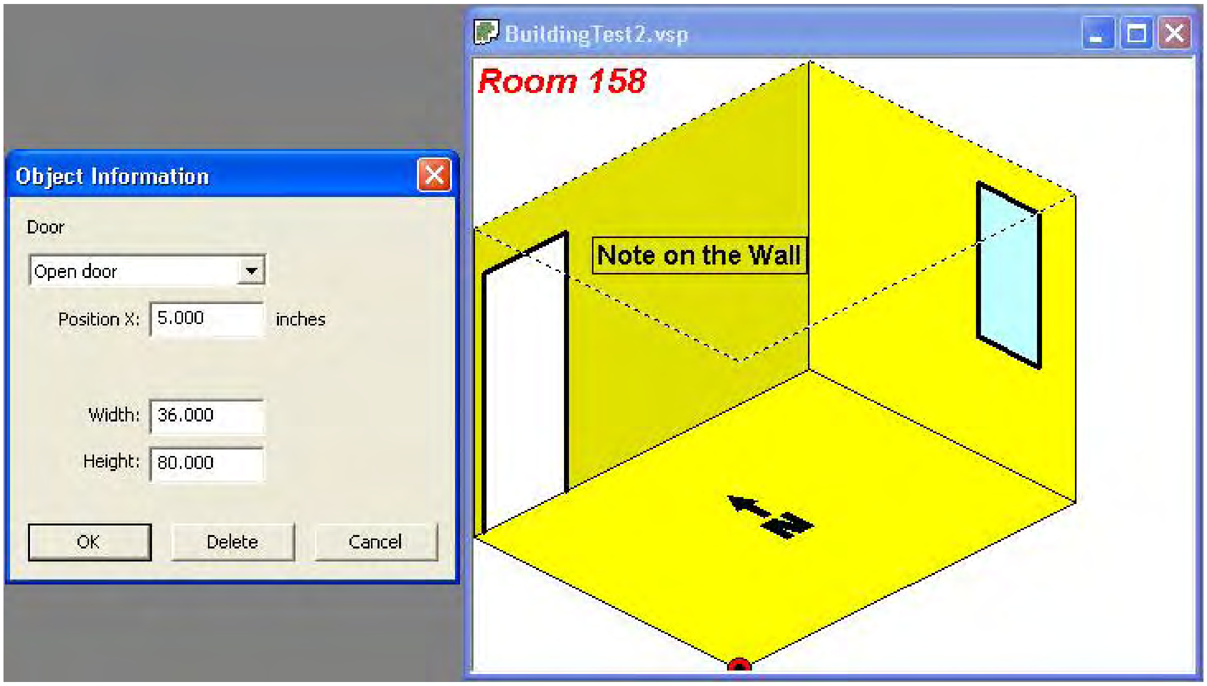


Figure 6.9. Object Information Dialog Box

To use the command in the Map View, click on one edge of the window and then on the other edge of the window. The window will be placed and sized with default heights. The edge coordinates can also be entered on the keyboard. Hold the shift key while clicking to attach the window to the nearest point on the map. Both edges of the window must be on the same wall section. Note that doors and windows are inserted into the current room (see section 6.2.1).

To use this command in the Room View, click on one corner of the window and then on the opposite corner of the window.

Windows can be moved, resized or deleted by using the **Room Object Information** dialog which is access by right clicking on the door. This dialog also allows you to change the door sub-type: Open Window (sample locations will be excluded from the window surface) or Fixed Window (sample locations will be included on the window surface).

6.3.3 Notes

To insert a note object into the current room, use the **Room > Insert Annotation** menu command (or **Insert Note** tool button). This command can be used only in the Room View.

Click on the location where you want to place a note. The text, font, color and other attributes can be modified from the Annotation Object Dialog box which is access by right clicking on the note. Notes can be moved by selecting them (by clicking on them) and then dragging them with the mouse.

6.3.4 Surface Overlays

One or more surface overlays can be inserted in a room to represent a portion of a surface that needs to be distinguished from the overall surface. For example, a portion of the floor in a room may be covered with tile while most of the floor is covered with carpet, requiring a different sampling technique. A surface overlay may a elevated from the floor to represent the top horizontal surface of a desk, chair, cabinet, or shelf. Surface overlays can be placed on any surface in the room. Only floor overlays can be elevated.

To insert a surface overlay into the current room, use the **Edit** > **Surfaces** > **Create Surface Overlay** menu command (or **Insert Door** tool button) to bring up the surface overlay dialog box (Figure 6.10). This command can be used only in the Room View (preferably the Perspective Room View). Choose the **Surface Type** from the drop down menu (too add a new surface type, go to **Edit** > **Surfaces** > **Surface Types**). Then click two opposite corners on the room's floor. This will create a rectangular shaped box on the room's floor. Change this to an elevated surface by right-clicking on it and change the **Height Above Floor** (and the sample placement parameters). An example of an elevated surface overlay is in Figure 6.11. Checking the "Allow samples on surface" box will allow sampling on the elevated surface when sampling in the room. Checking "Allow samples on floor beneath surface" allows for sampling to occur underneath the elevated surface.

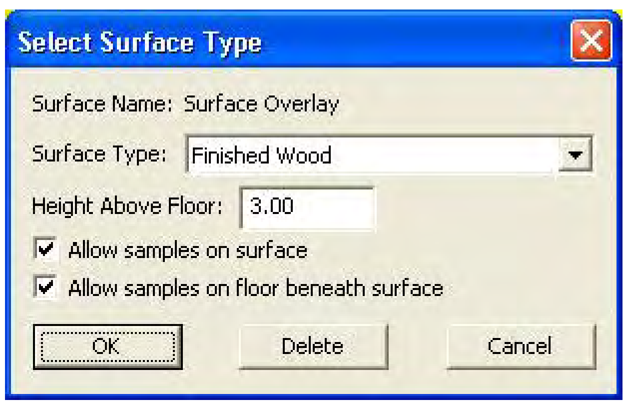


Figure 6.10 Surface Overlay Dialog

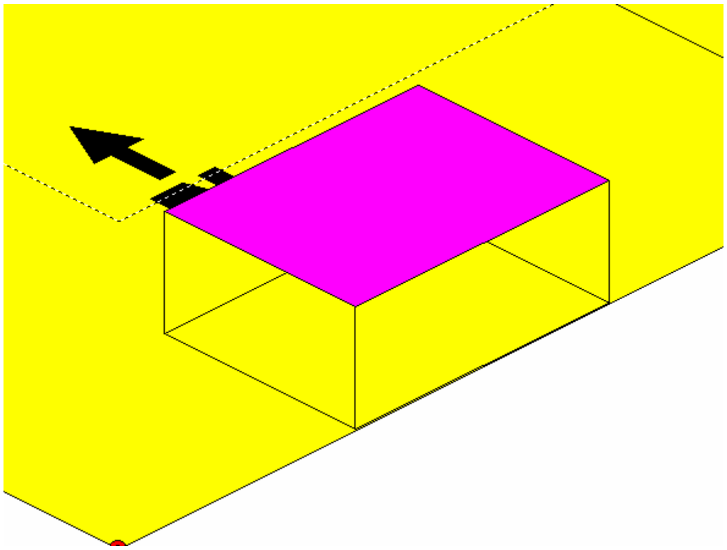


Figure 6.11 Surface Overlay

6.4 Other Room Features

6.4.1 Surface Labels

To automatically create a label (annotation or note object) on each surface of a room, use the **Room** > **Label Surfaces** command. This command creates a label for each surface in the current room when used in the Room View, or for all selected rooms when used in the Map View. The default labels are:

Floor
Ceiling
Wall 1
Wall 2
Wall …

This command allows you to choose the Font Type, Size, Style and Color as well as other attributes associated with labels. Figure 6.10 shows room surface labels.

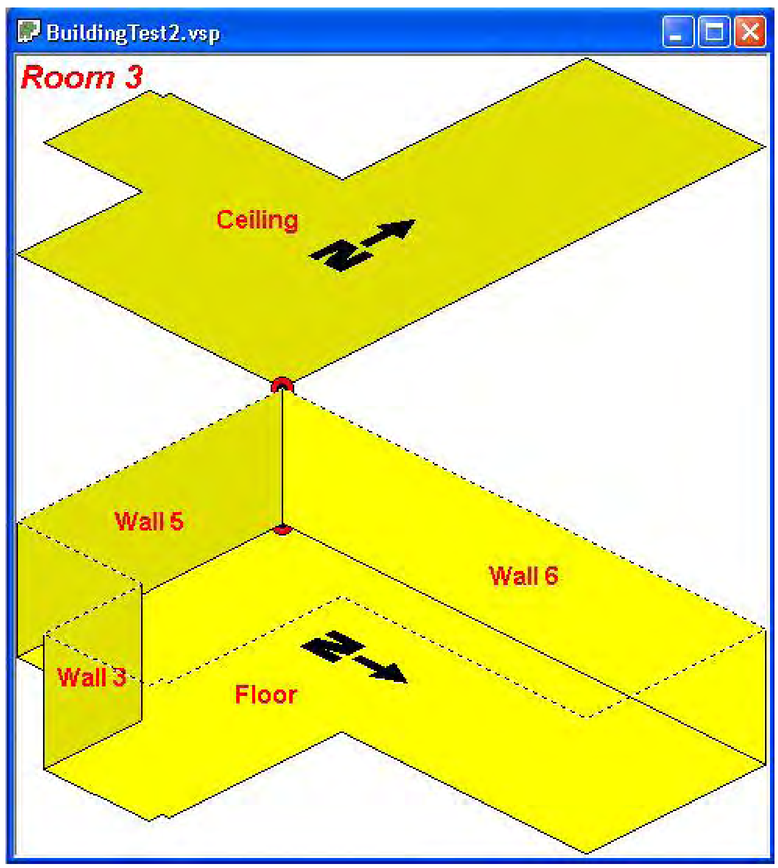


Figure 6.12. Room Surface Labels

After being created, the surface labels may be edited by right-clicking on them. If this command is run again, it will delete any existing label surfaces and replace them with the default surface labels. The surface label is also reported on the Sample Information dialog (accessed by right-clicking on a sample location). Figure 6.11 shows a Sample Information dialog with a custom surface label.

6.4.2 Local Coordinates and Room Origin

VSP uses local coordinates to facilitate the location of samples inside of rooms (and also regular sample areas). Local (LX, LY) are relative coordinates. Local coordinates can be viewed on the Sample Information dialog in Figure 6.11.

In regular Sample Areas, the local coordinates are relative to the minimum X and minimum Y coordinates of the sample area.

In Rooms, the local coordinates are relative to the surface they are on. For walls, the local coordinates are relative to the lower left hand corner of the wall section as you are facing it. For the floor and ceiling, the local coordinates are relative to the **Room Origin**. The location of Room Origin is shown on the Room View by a red and black bull's-eye.

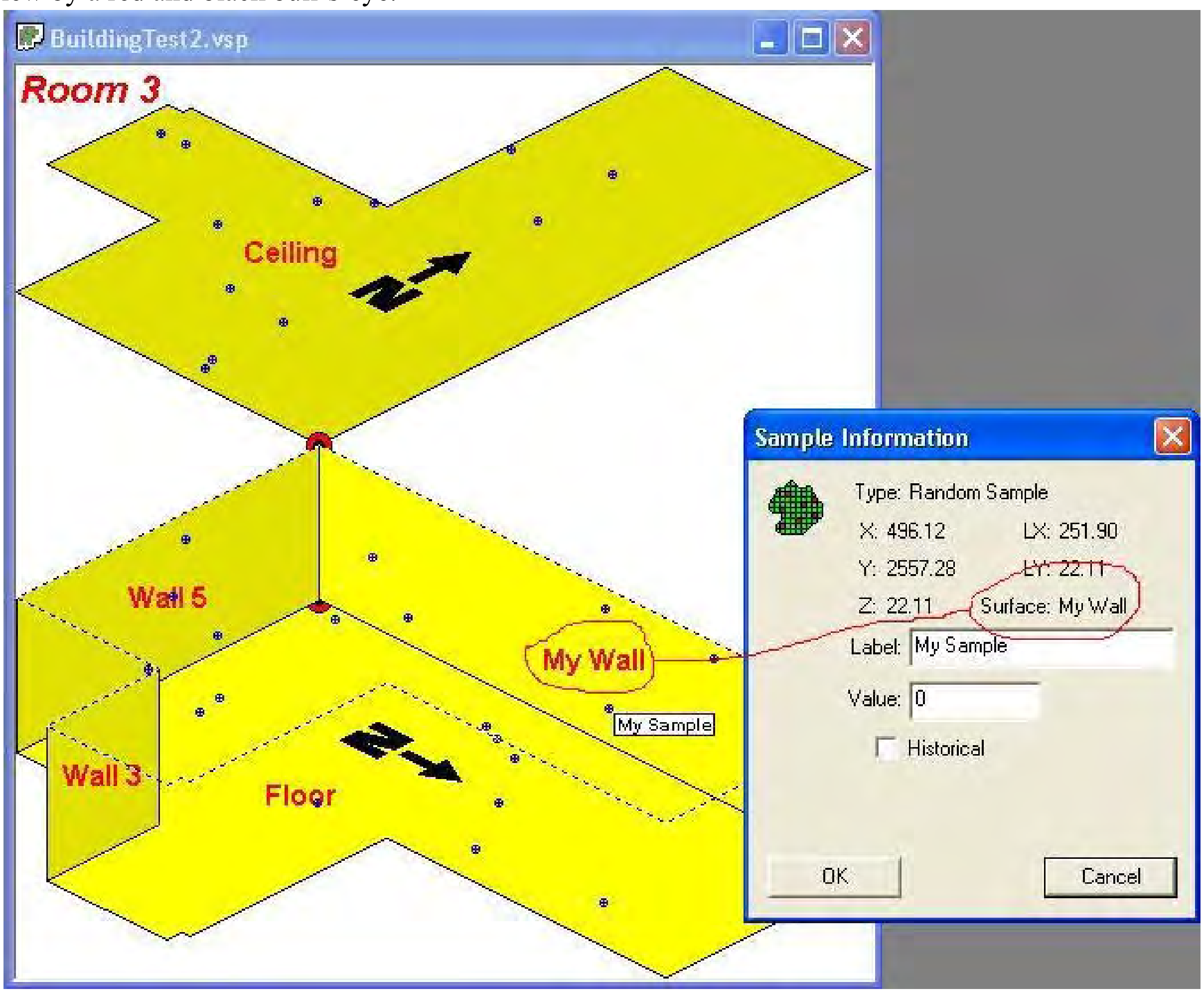


Figure 6.13. Room Surface Labels

By default the Room Origin is the minimum X and minimum Y, but can be changed with the **Room > Set Room Origin** menu command. Select the new location for the Room Origin by clicking on the Map. Hold down the Shift key while clicking to attach the Room Origin to an existing point on the map. The Room Origin can also be set by entering the coordinates on the keyboard.

6.4.3 Room Label

VSP provides a fixed room label at the upper left corner of each Room View. Although this label cannot be hidden, the font, color and other label attributes can be modified by left clicking on the label. The same color and styles are used for each Room View.

7.0 Unexploded Ordnance Features Within VSP

VSP contains several tools for statistical site characterization protocols of sites potentially contaminated with unexploded ordnance (UXO). These site characterization protocols help identify and delineate potential target areas at a site using limited amounts of geophysical transect data (Hathaway 2007). Tools include approaches for transect design, target identification, boundary delineation, and geophysical anomaly density mapping. The different topics and their corresponding sections in this guide are as follows:

- transect spacing needed to locate a UXO target area (Section 7.1)
- locating and marking UXO target areas based on elevated anomaly density (Section 7.2)
- geostatistical mapping of anomaly density and delineation of target areas (Section 7.3)
- assessing probability of target traversal based on actual transect pattern (Section 7.4)
- assessing degree of confidence in UXO presence (Section 7.5).

7.1 Transect Spacing Needed to Locate a UXO Target Area

Geophysical surveys are conducted at DoD sites and facilities to search for target areas at which munitions were fired or dropped. Surface areas passed over by geophysical detectors, referred to as transects, are usually up to several meters wide and run in a relatively straight line (as much as terrain permits) from one point of a site to another. When a geophysical sensor system is deployed continuously along transects, anomalous readings may be recorded. A goal of these surveys is to identify areas of high anomaly density consistent with that of a target area. The transect design methods in VSP are statistical approaches for determining the level of confidence in whether a transect sampling design will traverse and/or detect a target area of a specific shape, size, and anomaly density.

Selecting **Sampling Goals** > **Find UXO Target Areas** > **Transect spacing needed to locate a UXO target area** accesses the VSP tools that calculate the probability that at least one transect will traverse a target area of specified size and shape or estimate the probability the target area will be traversed and detected with a specific transect design, assumed background density, and target area density. In addition to these two methods, the user can manually place transects within a sample area.

Table 7.1 lists the variables that can be adjusted in this dialog and identifies which transect design method uses the variable. The three different methods are identified as Traversal, Traversal and Detection, and Manual in Table 7.1. The “additional information” column provides general information about the variable. Each of these variables will be described in more detail in the following sections. The first four variables listed in the table (Transect Pattern, Transect Width, Target Area Shape, Target Area Orientation) are generally defined by the survey equipment and the specific site use. The design objective selected will determine the importance of the remaining variables. The design objectives are specifically stated in VSP as “Ensure High Probability of Traversal Only” (traversal), “Ensure High Probability of Traversal and Detection” (traversal and detection), and “Manual Transect Spacing” (manual).

Of the three transect design methods, the traversal and detection design objective provides the most valuable information about the specific transect design selected. However, as Table 7.1 shows, it requires knowledge and input for many more variables than the other two. The traversal design guarantees that the assumed target area will have a specified probability of being traversed but falls short of any estimate that the target area will actually be identified.

Table 7.1. Variables That Can Be Adjusted in the "Transect Spacing Needed to Locate a UXO Target Area" Design Dialog with Selected Additional Information About the Variable and If the Variable Is Used in One of the Three Transect Design Methods

Variable	Additional Information	Traversal	Traversal and Detection	Manual
Transect pattern	Select from Parallel, Square, Rectangular designs	x	x	x
Transect width	Enter value in meters, feet, or inches	x	x	x
Target area shape	Select from area, length of axes, shape	x	x	
Target area orientation	Select random or enter known degrees	x	x	
Required probability of traversing target	Enter value between 50 and 100	x		
Transect spacing	Enter value in units defined by the map in use			x
Starting location	Select from random or fixed X,Y location on the map			x
Background density	Enter value in acres, hectares, or square feet, meters, inches, kilometers, or miles		x	
Background decision rule	Stated in terms of percent confident density > bkg		x	
Instrument false negative rate	Enter any value between 0 and 50		x	
Proposed evaluation transect spacing	Enter the minimum and maximum transect spacing in the same units as the map		x	
Target area density (above background) range	Enter the minimum and maximum density in the same units as background density		x	
Target area density above background	Enter value in same units as background density		x	
Target area density distribution	Uniform or bivariate normal		x	
Density input	Used only for the bivariate normal target area density distribution. Select outer edge, center, or average of the target area		x	
Minimum precision	A proportion between 0.05 and 0.20		x	
Maximum error	A proportion between 0.005 and 0.10		x	
Search window diameter	Enter value in units defined by the map in use		x	

7.1.1 Survey and Target Area Pattern

The "Survey and Target Area Pattern" tab shown in Figure 7.1 is used to enter information about the transect pattern of interest, the transect width (width of the area covered by the geophysical detector), the size and shape of the target area, and the angle between the major axis of the target area and the transects.

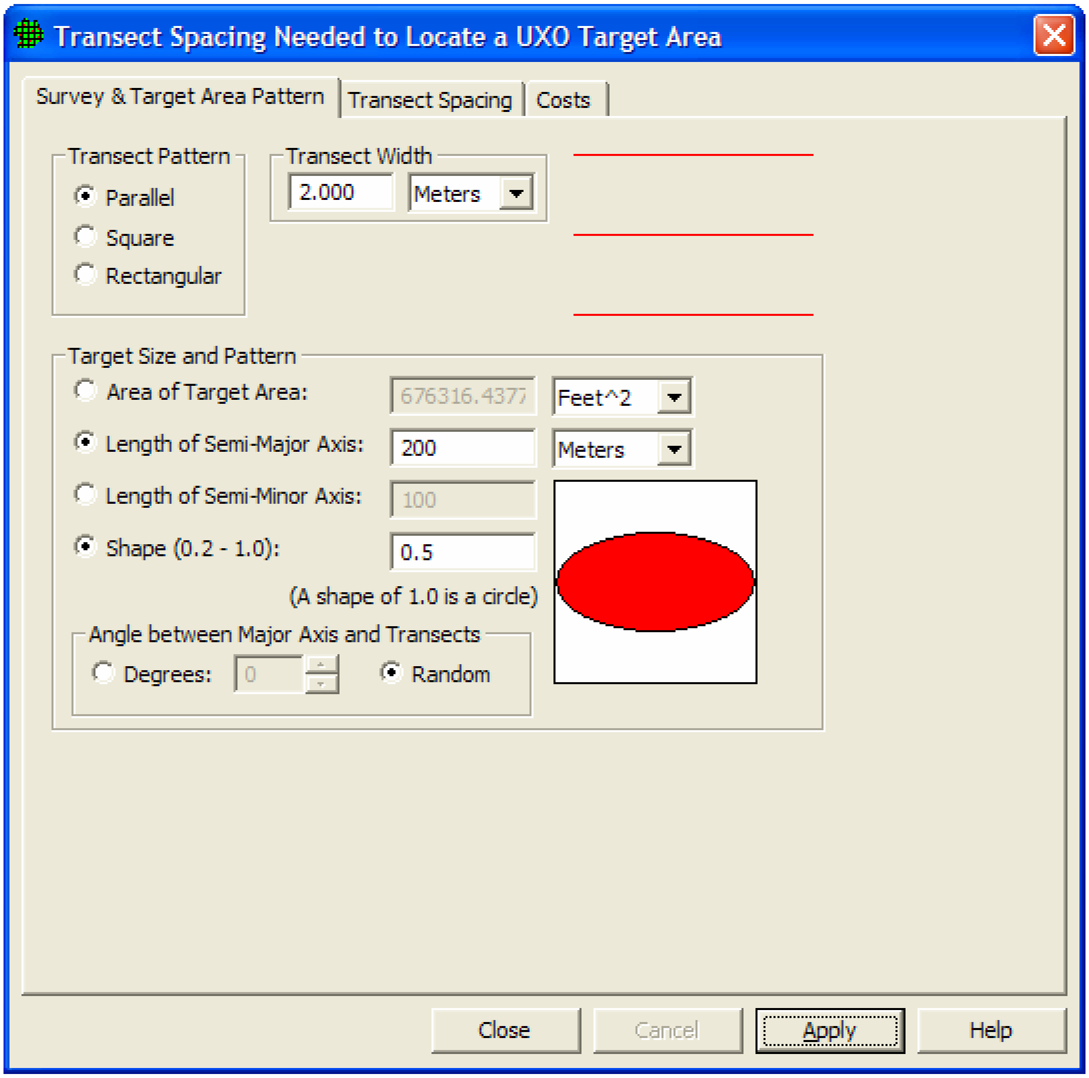


Figure 7.1. Survey and Target Area Pattern Tab

7.1.1.1 Transect Pattern

In the example shown in Figure 7.1, a parallel transect pattern has been specified under the "Transect Pattern" section in the upper left corner. In the upper right section, a visual example of the transect pattern is displayed showing three red lines that represent parallel transects. Figure 7.2 shows the visual examples for all three types of transect patterns: parallel, square, and rectangular.

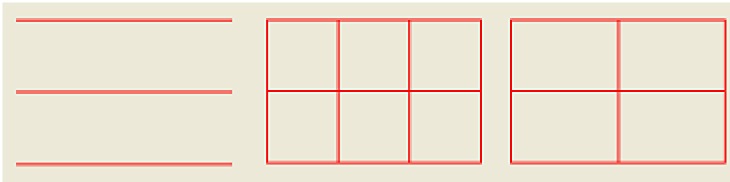


Figure 7.2. Transect Patterns: Parallel (left), Square (middle), and Rectangular (right)

7.1.1.2 Transect Width

The width of the transects is entered under "Transect Width." The transect width, which is dependent on the "sensor footprint," is the width of the area on the ground surface for which the geophysical detector passes over and collects data. Units can be entered in feet, meters, or inches. The transect width along with the transect length determine the amount of surface area a transect covers.

7.1.1.3 Target Size and Pattern

In the "Target Size and Pattern" section of Figure 7.1, different options are available for entering the size and shape of the target area. Options include entering the major axis and minor axis, entering the major axis and shape, or entering the area of the target and shape. There also is an option for fixing the angle of the target in relation to transects or allowing this to be random (the default). The *Area of Target Area* is the total surface area over which the target area lies. The *Semi-Major Axis* and *Semi-Minor Axis* are the widths of the distance from the target area center to its perimeter at its widest and narrowest points, respectively, as illustrated in Figure 7.3**Error! Reference source not found.**. The *Shape* of the target is the ratio of the semi-minor axis to the semi-major axis. The shape will never be greater than 1 and has a lower-limit of 0.2.

When the identified target area is not a circle, the angle of orientation between the target area major axis and the transect orientation on the map can be defined or marked as random in the "Angle between Major Axis and Transects" section of Figure 7.1. It is recommended that "Random" be used unless very reliable information is known about the target location and the direction from which the target was fired upon. If this information is available and the angle of the target's semi-major axis is known with near certainty, then "Degrees" may be selected and the angle is entered in degrees. When this information is known, it can have a significant effect on the final transect design.

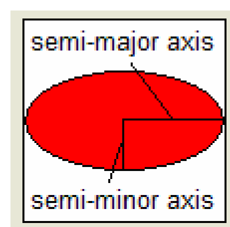


Figure 7.3. Semi-Major Axis and Semi-Minor Axis on an Ellipse

7.1.2 Transect Spacing

The "Transect Spacing" tab shown in Figure 7.4 is used to enter information about the design objective and parameters needed to assess those objectives other than those covered in the "Survey and Target Area" tab.

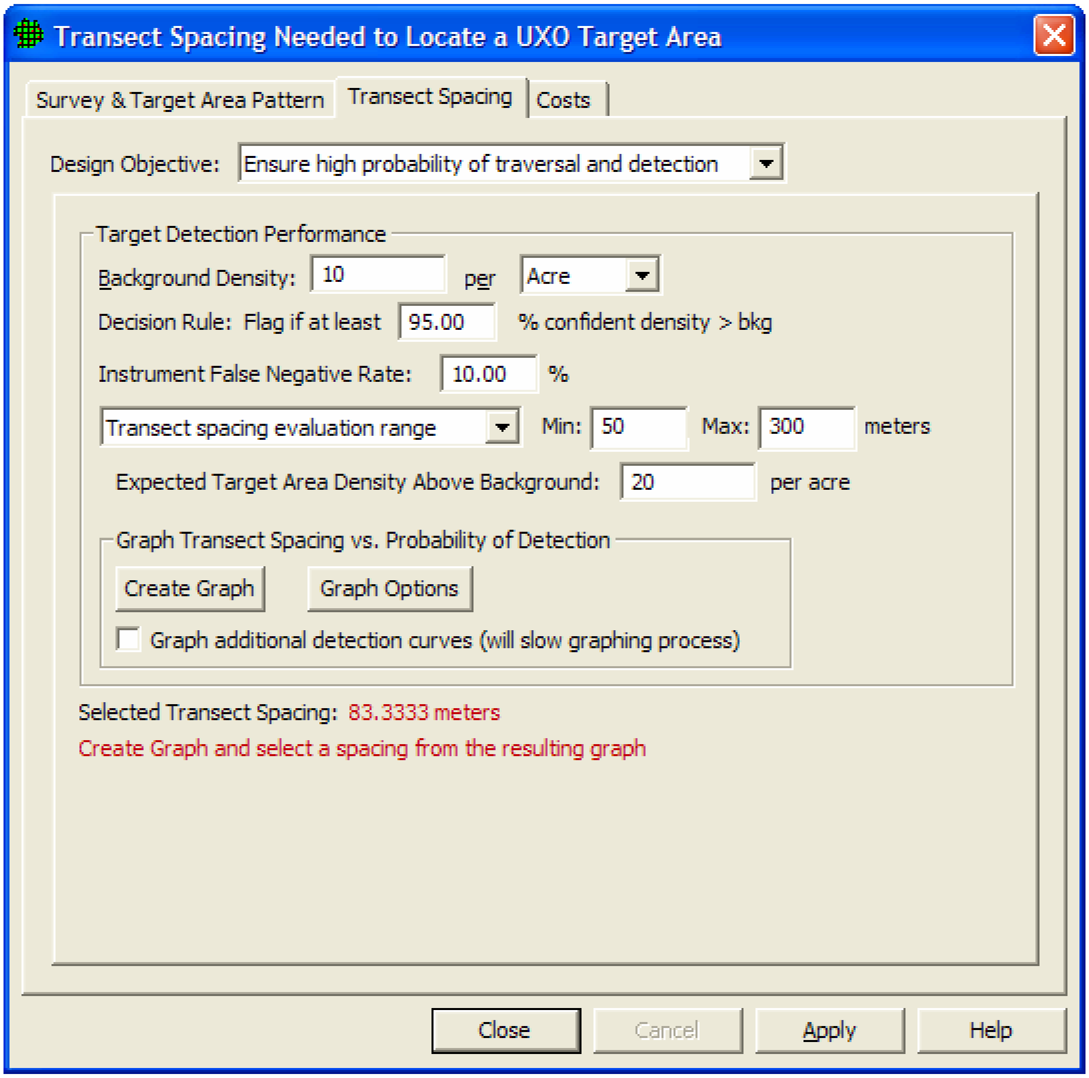


Figure 7.4. Transect Spacing Tab for Design Objective "Ensure High Probability of Traversal and Detection" and "Transect Spacing Evaluation Range"

7.1.2.1 Design Objective

There are three design objectives to choose from: 1) Ensure high probability of traversal and detection," 2) Ensure high probability of traversal only, and 3) Manual transect spacing. Each of these design objectives and their required parameters are explained in Sections 7.1.2.1.1 through 7.1.2.1.3.

Figure 7.4 shows the Transect Spacing tab when "Ensure high probability of traversal and detection" is selected as the Design Objective and "transect spacing evaluation range" is selected from the drop-down menu under Target Detection Performance. Figure 7.5 shows the Transect Spacing tab for the same Design Objective for when "TA density (above background) range" is selected from the drop-down menu.

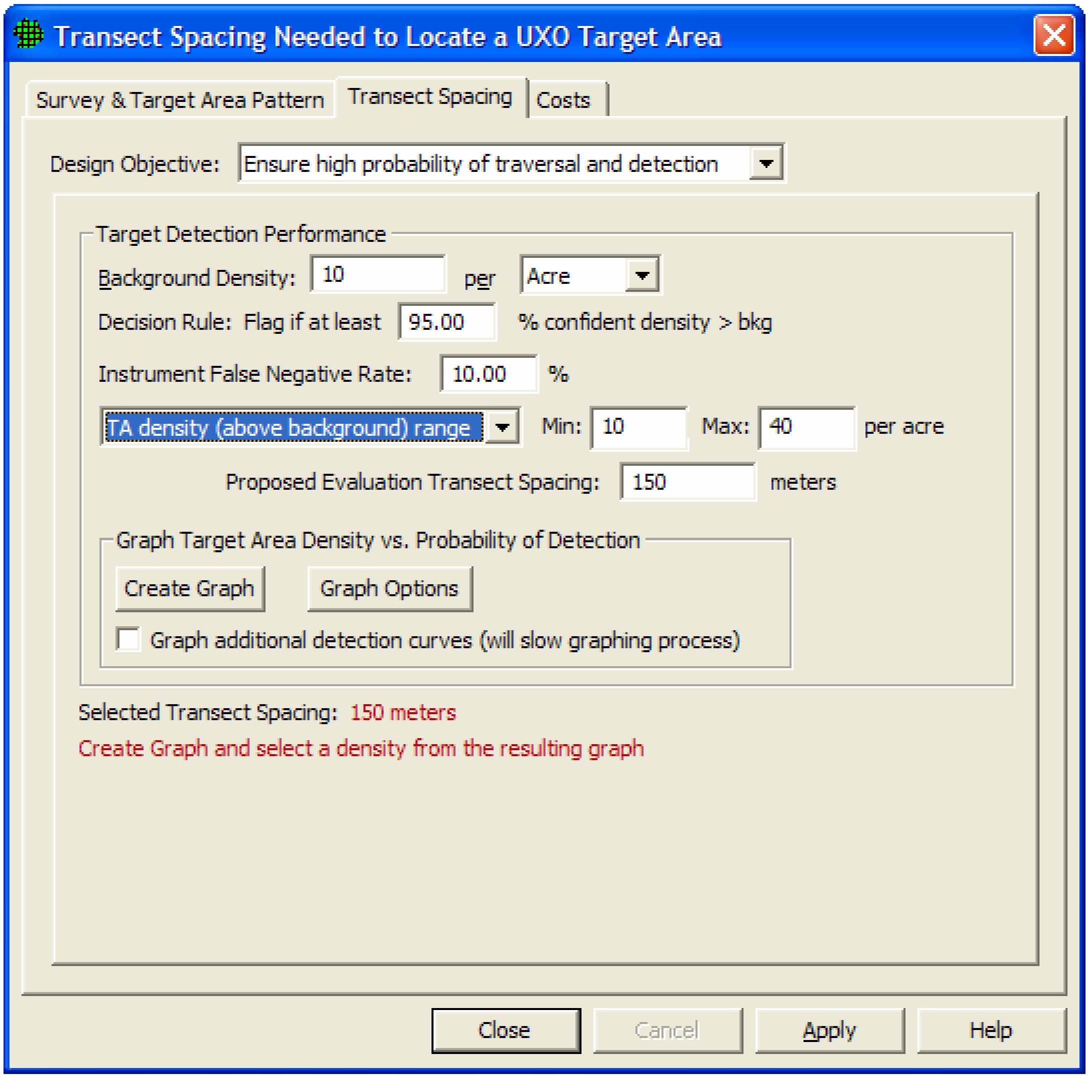


Figure 7.5. Transect Spacing Tab for Design Objective "Ensure High Probability of Traversal and Detection" and "TA Density (above background) Range"

The *Background Density* of a site is the expected density in an area where anomalies occur solely from geologic material or anthropogenic clutter not related to DoD range activities. These background anomalies are treated as if they are uniformly distributed throughout the site. Areas containing UXO and other munitions-related anomalies are expected to have density greater than background.

The *Decision Rule* is the required percent confidence that an area has density greater than background density needed to conclude it is an area of interest. VSP evaluates a number of "windows," which are circular areas centered along transects. The Decision Rule refers to the percent confidence for an individual window. VSP will "flag" an area that appears to have density higher than background density according to the decision rule. An area is flagged if the actual density is significantly higher than the expected background density. In statistical terms, the decision rule is $1 - \alpha$ expressed as a percentage, where α is the probability of a type I error, or the probability of concluding an area has density greater than background when it is truly a background area.

The *Instrument False Negative Rate* accounts for the fact that collected data may not be representative of the actual density because the geophysical detector may not detect all anomalies. For example, a false negative rate of 5% would indicate the detector, on average, would fail to detect 5% of the total anomalies traversed. If it were assumed that the detector always detects individual anomalies, then a false negative rate of 0% would be used.

Min and *Max* refer to a range of transect spacings or target area anomaly densities (above background) to evaluate. When the design objective is *Ensure high probability of traversal and detection*, the user has the option of choosing to produce a *TA density (above background) range* or a *transect spacing evaluation range*. When working with a *transect spacing evaluation range*, users must enter the *Min* (minimum) and *Max* (maximum) transect spacings they want to consider. For rectangular transect patterns, this refers to the set of transects with the more narrow transect spacing. Thus, if a user wants to evaluate a range of transect spacings, he would enter this range as the *Min* and *Max*. VSP will evaluate the transect spacings *Min* and *Max* in addition to spacings between those values. When *TA density (above background) range* is chosen, *Min* and *Max* refer to the target area density above background. VSP will evaluate a range of target area densities above background to estimate how well the transect design will detect the target depending on the anomaly density of that target.

The *Expected Target Area Density Above Background* in Figure 7.4 is the anomaly density of the target (excluding background density) when *transect spacing evaluation range* is selected. To evaluate a range of transect spacings, the anomaly density of the target remains fixed.

The *Proposed Evaluation Transect Spacing* in Figure 7.5 is the transect spacing to use when *TA density (above background) range* is selected. To evaluate a range of target densities, the transect spacing remains fixed. The *Graph Additional Detection Curves box* works as described in the preceding paragraph with density and transect spacing interchanged.

Checking the *Graph Additional Detection Curves* box will produce two additional curves on the graph for the density or transect spacing specified. The additional curves will be for one half and twice the fixed input variable. This allows for the examination of the sensitivity of both changes in transect spacings and changes in target density on the same graph. Because this requires additional simulations for the additional curves, this option increases the simulation run time.

The *Graph Options* button brings up the additional dialog in Figure 7.6.

The user can choose between a *Uniform Density* and a *Bivariate Normal Density* for the distribution of anomalies, excluding background, within the target area. If Uniform Density is chosen, the distribution of anomalies within the target area is assumed to be randomly distributed throughout the entire target area. If Bivariate Normal Density is chosen, the distribution of anomalies within the TA is assumed to be biased toward higher densities in the center of the TA such that the densities from the TA center to the TA perimeter follow an approximately normal curve.

Average Target Area Density (above background) defines how the density value inputs for the *Bivariate Normal Density* are entered when selected (this option is disabled when *Uniform Density* is selected). The default is that target area densities are entered as the *Target Average*, or average anomaly density (above background) of the target. Also available are Outer Edge of Target and Center of Target, which refer to the density near the perimeter of the target area and the center of the target area, respectively. Changing to one of these options will allow the user to enter target area densities for the target edge or center instead of the target area average anomaly density.

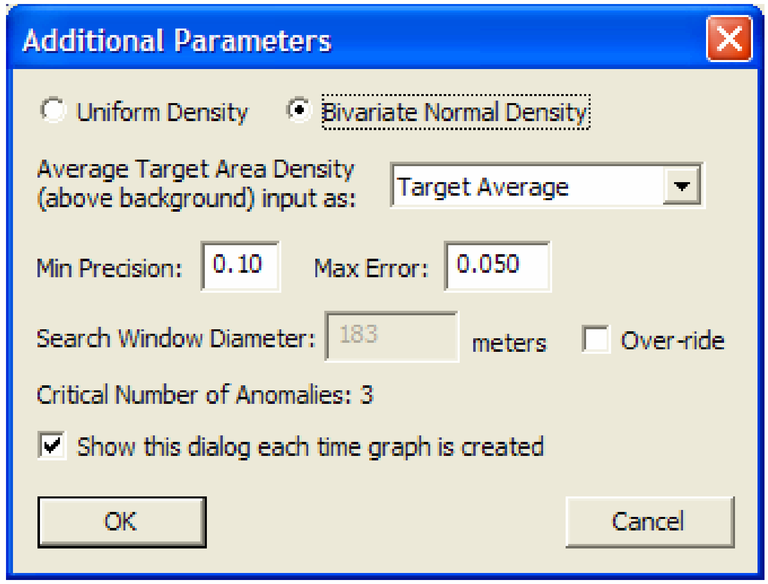


Figure 7.6. Graph Options

Min (Minimum) *Precision* is used to determine the number of different TA densities or transect spacings to simulate. Decreasing the *Min Precision* typically requires more transect spacings or densities to be simulated and increases the length of the simulation. Increasing the *Min Precision* will typically decrease the length of the simulation.

Max (Maximum) *Error* determines the number of iterations for each transect spacing or density simulated. Decreasing the *Max Error* requires more simulations for each transect spacing or density simulated and increases the overall simulation time. Increasing the *Max Error* will decrease the simulation time.

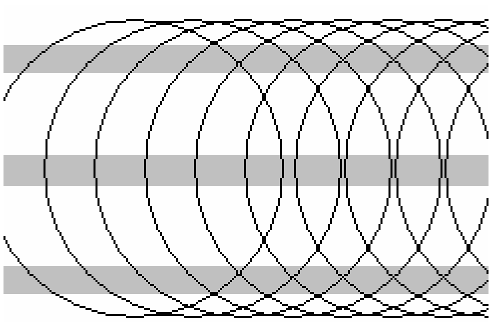


Figure 7.7. Example of Windows Moving Along the Center Transect Shown

The *Search Window Diameter* refers to the diameter of the circular search window used to identify areas in which density is greater than background density. The window is actually a moving window that moves in increments of one-sixth the window diameter along each transect, as shown in Figure 7.7. Each search window is evaluated to determine if the density is significantly greater than background density. VSP calculates a default window diameter for the current design, but checking the *Override* box allows the user to manually enter a window diameter. The *Critical Number of Anomalies* refers to the number of detected anomalies required inside a window to identify it as significantly greater than background.

Checking the *Show this dialog each time graph is created* has the dialog box in Figure 7.6 appear after pressing the *Create Graph* button (Figure 7.4 and Figure 7.5) but before simulations are run and a graph is produced. Otherwise, pressing the *Create Graph* button will skip this step and proceed with running simulations followed by producing a graph.

An example of the resulting graph, or power curve, for this tool is shown in Figure 7.8, where *Transect spacing evaluation range* was selected and the *Graph Additional Detection Curves* box was checked. This graph shows the effectiveness of a range of transect spacings for detecting the target area. It also shows the sensitivity of detecting the target area for different target area densities.

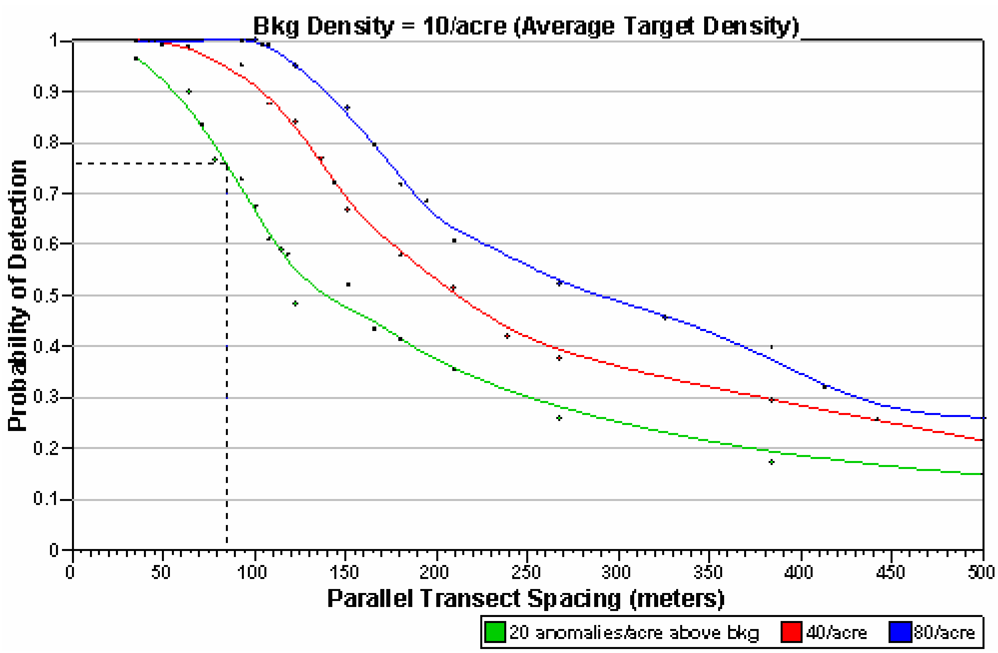


Figure 7.8. Power Curve with Transect Spacing as the X-Axis and Additional Curves Displayed

Figure 7.9 shows the Transect Spacing tab when "Ensure high probability of traversal only" is selected as the Design Objective. A subset of the parameters used for "Ensure high probability of traversal and detection" is used for this dialog with one new parameter, *Required Probability of Traversing the Target*. This is the required probability the design chosen will traverse the target area. VSP calculates the transect spacing required to achieve this probability and displays the result in red text. Definitions for the other parameters are the same as those in Section 7.1.2.1.1. These parameters allow the user to specify the *Target Area Density Evaluation Range* to examine how well the transect design will detect the target area for different target area densities.

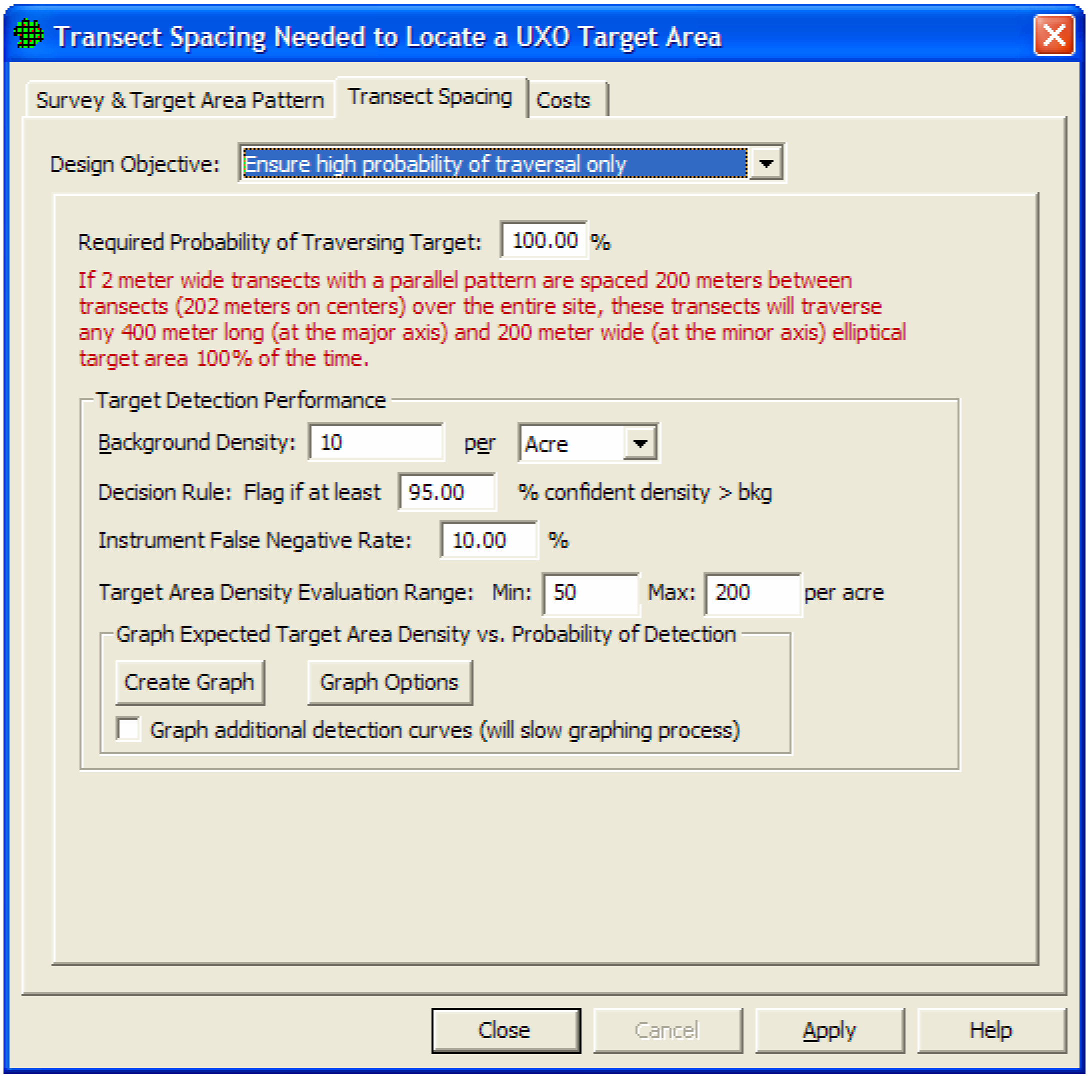


Figure 7.9. Transect Spacing Tab for Design Objective "Ensure High Probability of Traversal Only"

Figure 7.10 shows the Transect Spacing tab when "Manual transect spacing" is selected as the Design Objective. This option makes available some of VSP's useful features without using data quality objectives. Before deciding to develop a sampling plan based on a user-supplied transect spacing and starting location, consider the assumptions and limitations involved.

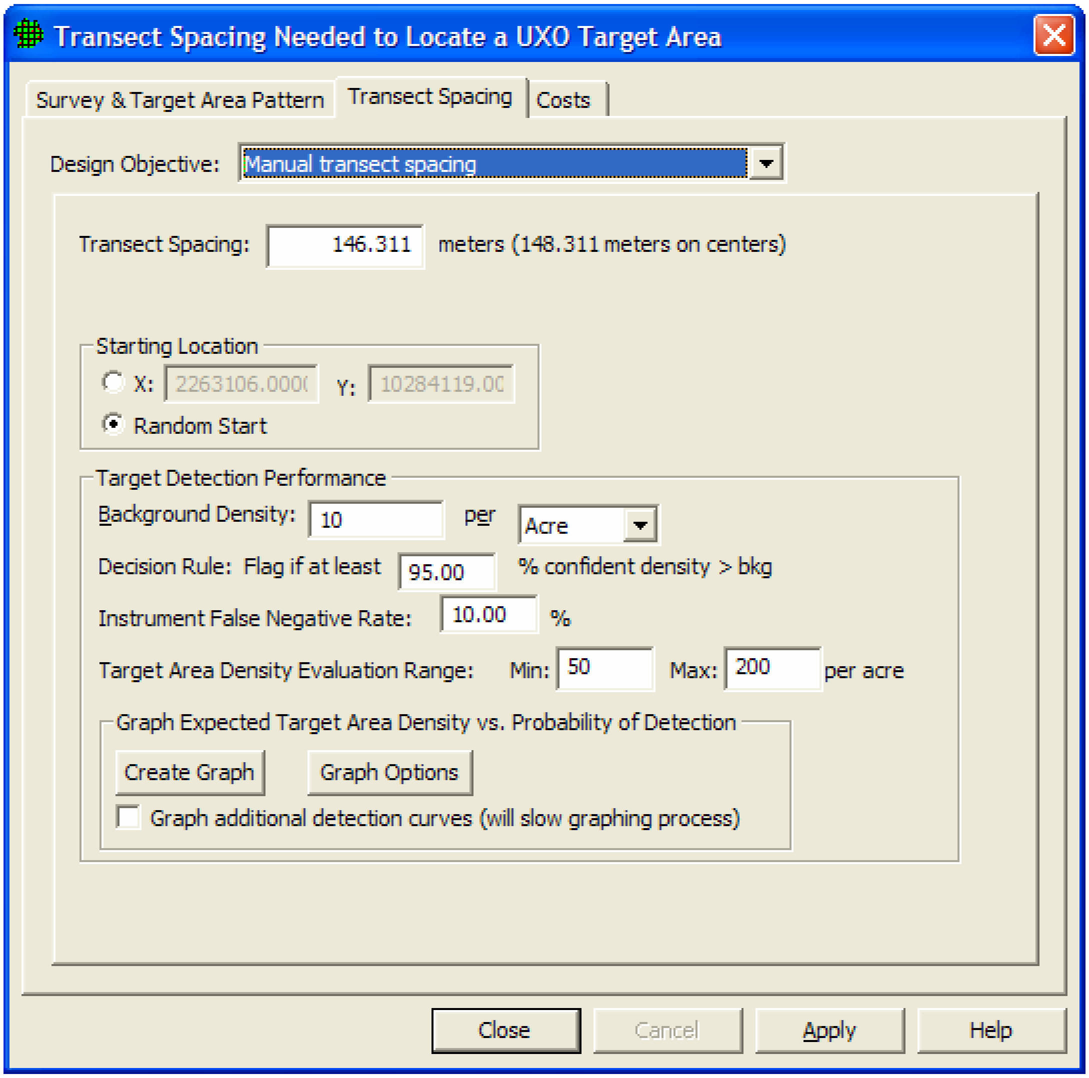


Figure 7.10. Transect Spacing Tab for Design Objective "Manual Transect Spacing"

7.1.3 Costs

The Cost tab provides an estimate of costs using the chosen transect design on the current VSP map. The user must enter the *Fixed Planning and Validation Costs*, *Setup Cost per Transect*, and *Collection Cost per Linear Unit* to calculate the *Total Cost of Transect Sampling*.

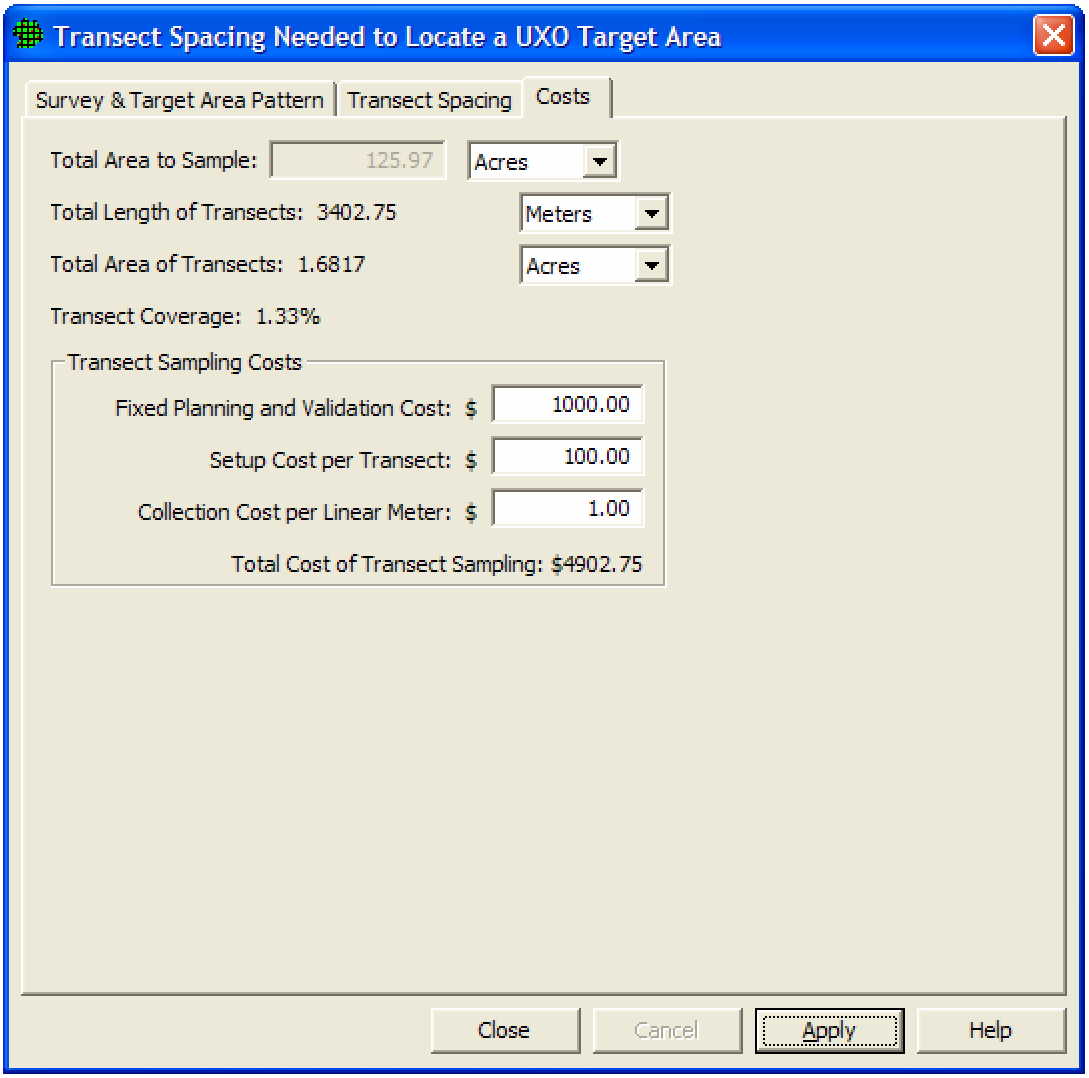


Figure 7.11. Costs Tab for Transect Spacing Needed to Locate a UXO Target Area

7.2 Locate and Mark UXO Target Areas Based on Elevated Anomaly Density

Once a transect design has been accepted and the geophysical survey completed, the surveyed data (i.e., the transect course-over-ground and anomaly location data) is imported into VSP and analyzed. This process is begun in VSP by selecting **Sampling Goals > Find UXO Target Areas > Locate and mark UXO target areas based on elevated anomaly density**. Section 7.2.1 details how these data can be imported and manipulated in VSP. Section 7.2.2 describes the methods used to evaluate the anomaly density distribution of the site and determine an appropriate critical density to identify high-density areas within it.

7.2.1 Data Entry – Importing Course-Over-Ground and Anomaly Files into VSP

The *Data Entry* tab shown in Figure 7.12 provides the ability to import ASCII (plain text) files identifying the course-over-ground (COG) and anomalies (anomaly) data. Table 7.2 shows an example of the COG file (left) and anomaly file (right) structure used within VSP. Oasis Montaj can be used to generate COG and anomaly files like those shown in Table 7.2 (Geosoft 2007). VSP can also import the COG and anomaly information if they are saved in common TXT and CSV formats. The two files shown in Table 7.2 show the most information that can be included in the file. At a minimum, the file to be imported must have two columns representing the X and Y coordinates in that order. The COG coordinates mark the X, Y location for the survey equipment path. Because the file does not provide transect width information, the user must obtain it from the survey team. The anomaly coordinates are locations where the survey team has identified an object of possible metallic origin.

Table 7.2. Example of ASCII Files That Can Be Imported into VSP for the Course-Over-Ground Transect Data and the Associated Anomaly Location Data

Example of COG File	Example of Anomaly File
/ --	/ --
/ CSV EXPORT [06/22/2007]	/ CSV EXPORT [06/22/2007]
/ DATABASE [.\07172015.gdb]	/ DATABASE [.\07172015_anomaly.gdb]
/ ---------------------------------------	/ ---
/	/
/X,Y,GPS_Time	/Fiducial,X,Y,Grid_value
//Flight 0	//Flight 0
//Date 2007/06/21	//Date 2007/06/22
Random GGK	Random 07172015_Targets
643636.04,4335445.66,76968.5	0,643685.125,4335486.500,40.21
643638.10,4335446.86,76970.5	1,643803.250,4335587.000,84.87
643641.17,4335449.01,76972.5	2,643907.750,4335681.125,45.61
643643.34,4335451.14,76974.5	3,643918.875,4335707.000,1119.21
643645.11,4335453.27,76976.5	4,643948.250,4335742.875,83.94
643646.96,4335455.55,76978.5	
643648.91,4335457.71,76980.5	
643650.77,4335459.62,76982.5	
643652.71,4335461.39,76984.5	
643654.58,4335463.04,76986.5	
643656.47,4335464.60,76988.5	
643658.61,4335466.29,76990.5	

The *Data Entry* dialog in VSP provides the user with the ability to import and identify all the necessary files for analysis. Figure 7.12 shows the "Data Entry" tab included in the "Locate and mark UXO target areas based on elevated anomaly density" and "Geostatistical mapping of anomaly density" dialogs. The tab provides import, export, removal, and file summaries for the COG and anomaly files in two separate boxes. When importing COG information, the user is prompted to define the width of the transects in the file before it is imported. VSP provides a summary that includes the file name, number of lines imported, width of the transects, and the units associated with the transect width. The anomaly data is imported and summarized in a similar manner. The "Sel" column shown in each box provides a method to manipulate individual files. If the box is blank, the file is not selected. When the user enters a “T,” then the identified files can be removed or exported from the project. If the box is marked next to “Mark points that are outside Sample Areas,” then any points in an imported file that fall outside the selected sample areas are shown as red lines. This feature helps the user identify locations where the survey went beyond the identified sample boundaries.

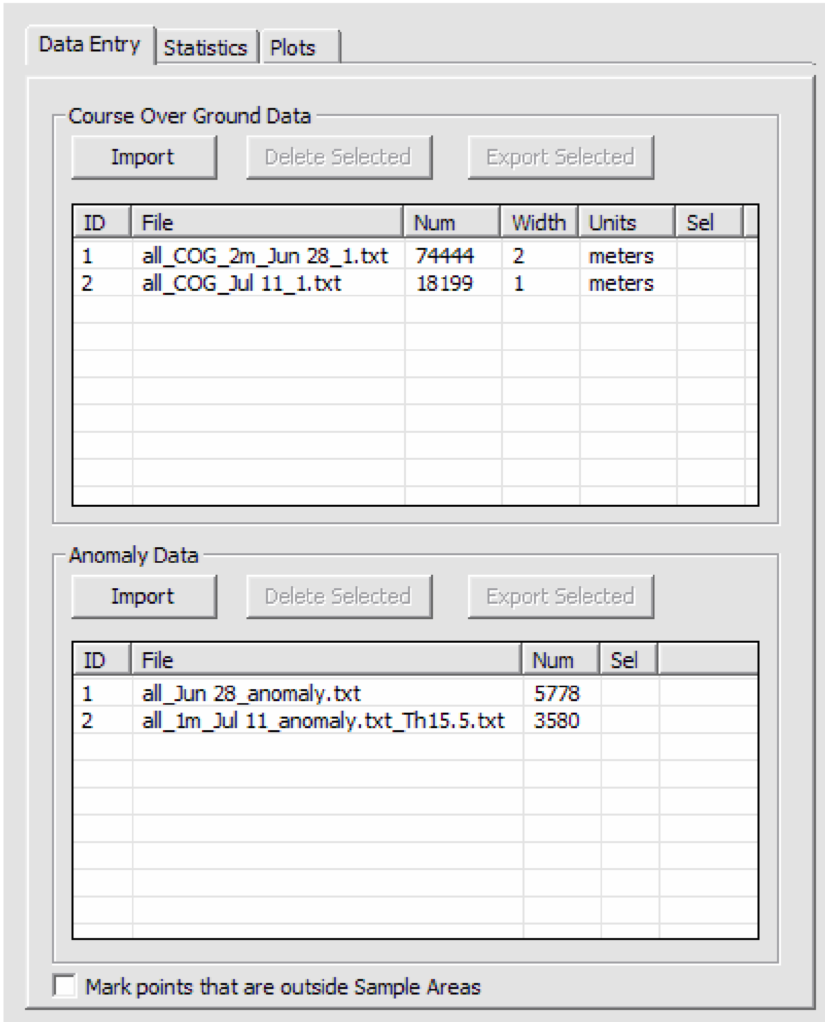


Figure 7.12. Data Entry Tab Found Within the “Find UXO Target Areas” Dialog and “Geostatistical Mapping of Anomaly Density” Dialog

7.2.2 Find Target Areas

After the sample area has been identified and the necessary files have been imported into VSP, the user can analyze the data. VSP provides two dialogs for analyzing the spatial data. This section details the dialog of the Find Target Areas tab when selecting **Sampling Goals > Find UXO Target Areas > Locate and mark UXO target areas based on elevated anomaly density**. This identifies locations within the transects that are identified as being high density (i.e., high number of anomalies within a specified amount of the surveyed transect area). The dialog for geostatistical methods is discussed in Section 7.3.

To identify high-density areas along transects, VSP passes a circular window over segments of the site and calculates the anomaly density for each window. The *Window Diameter* specifies the size of the circular area over which the average density is computed. This window diameter was previously explained in Section 7.1.2.1 when describing the *Search Window Diameter* and the associated search window. Figure 7.13 shows where the window diameter is selected in this VSP analysis dialog. Figure 7.14 provides an example of how the window diameter is used to calculate transect grid densities. The window diameter defines the size of a centered circular window (orange and blue circles in Figure 7.14), which moves every one-sixth the selected diameter and uses the anomaly count with the transect area within the window to calculate a density assigned to the central transect grid (orange and blue boxes in Figure 7.14) centered in the window. The green dots in Figure 7.14 represent the identified anomalies within the two surveyed transects. For transects with length less than one-sixth the window diameter, such as in course-over-ground data, the window may step over several transects.

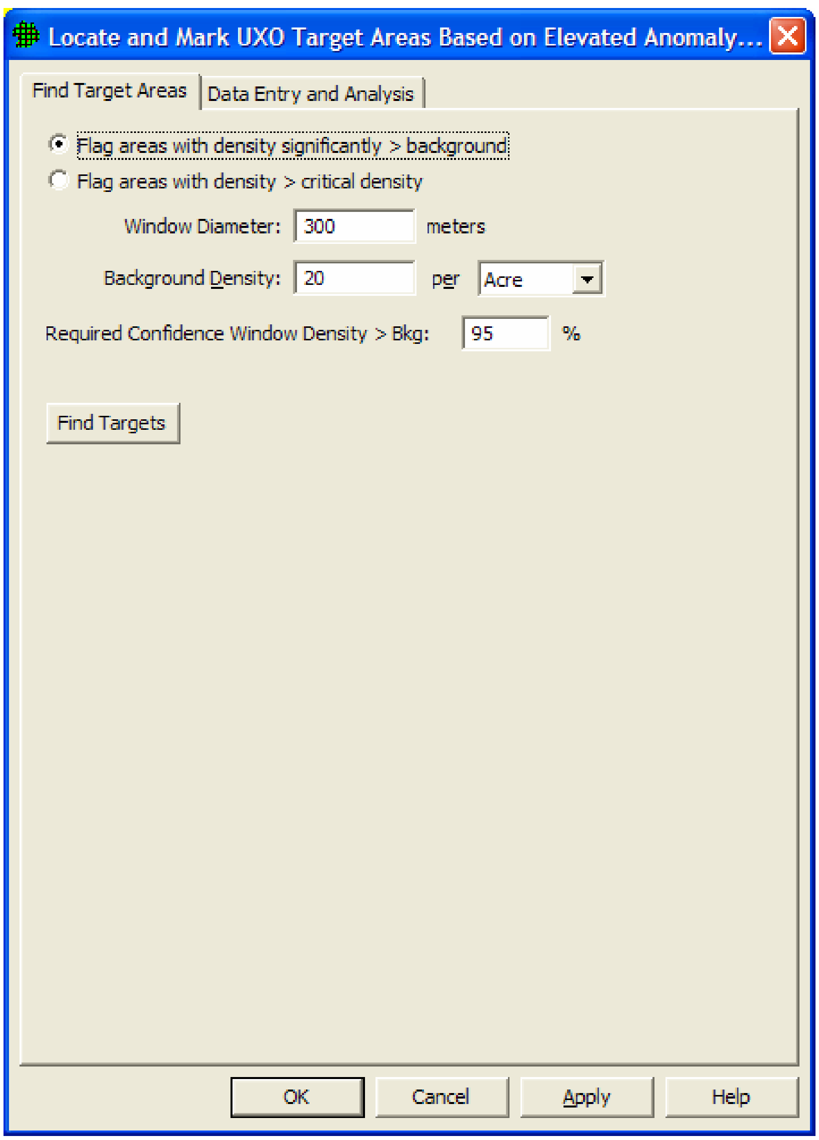


Figure 7.13. Find Target Areas Dialog When "Flag Areas with Density Significantly > Background" Is Selected

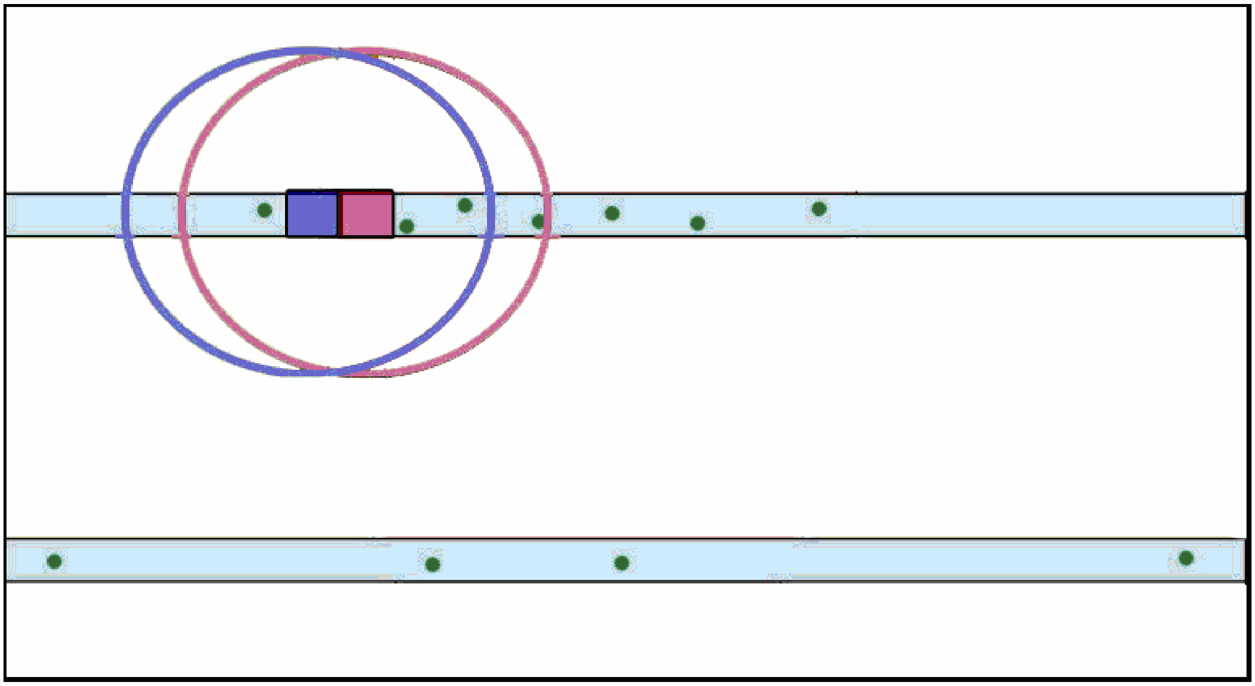


Figure 7.14. Depiction of the Window Density Calculation Process Used To Identify High-Density Regions Within a Site

The selection of an appropriate window diameter is dependent on the size of the target area of interest, transect width, and spacing between transects. The optimum window diameter is one that has sufficient traversed area within the window without including such a large area that potential high-density areas can be masked by the surrounding low-density areas in the window. As a general rule, the window diameter should be less than the diameter of the target area of interest and no smaller than the spacing between the original transect design. Selecting the appropriate window diameter for each specific site analysis is currently left to the user.

A circular search window is used to identify areas in which density is significantly greater than background density or greater than the critical density. The diameter of this window is entered as a parameter in the units to which the VSP map is set. The window is actually a moving window that moves in increments of one-sixth the window diameter along the transect path. Each search window will be evaluated to determine if the density is significantly greater than background density or greater than the critical density, depending on which option is chosen.

Figure 7.13 shows the dialog box when *Flag areas with density significantly > background* is chosen. This option performs a statistical test on each window to determine if the anomaly density in the window is significantly greater than background density. In addition to the *Window Diameter*, the user must enter the *Background Density* and *Required Confidence Window Density > Bkg (Background Density)*. These parameters were previously defined as *Background Density* and the *Decision Rule* used in Section 7.1.2.1.1.

When *Flag areas with density > critical density*, the *Window Diameter* and *Critical Density* are entered. VSP will flag any window whose calculated anomaly density is greater than the specified *Critical Density*.

When the Find Targets button is pushed, areas with high densities according to the inputs described above are flagged (marked with a box) on the VSP map. VSP also provides a histogram of anomaly densities across the site created by gridding the site, averaging the window densities in each grid, and displaying these averages in the histogram. This averaging ensures that areas of the site containing more transects will not be overrepresented in the histogram. A histogram of the density calculations for the entire site can provide a good understanding of the anomaly density distribution and can help in selecting the background density. Examples of three histograms are shown in Figure 7.15. The topmost histogram shows

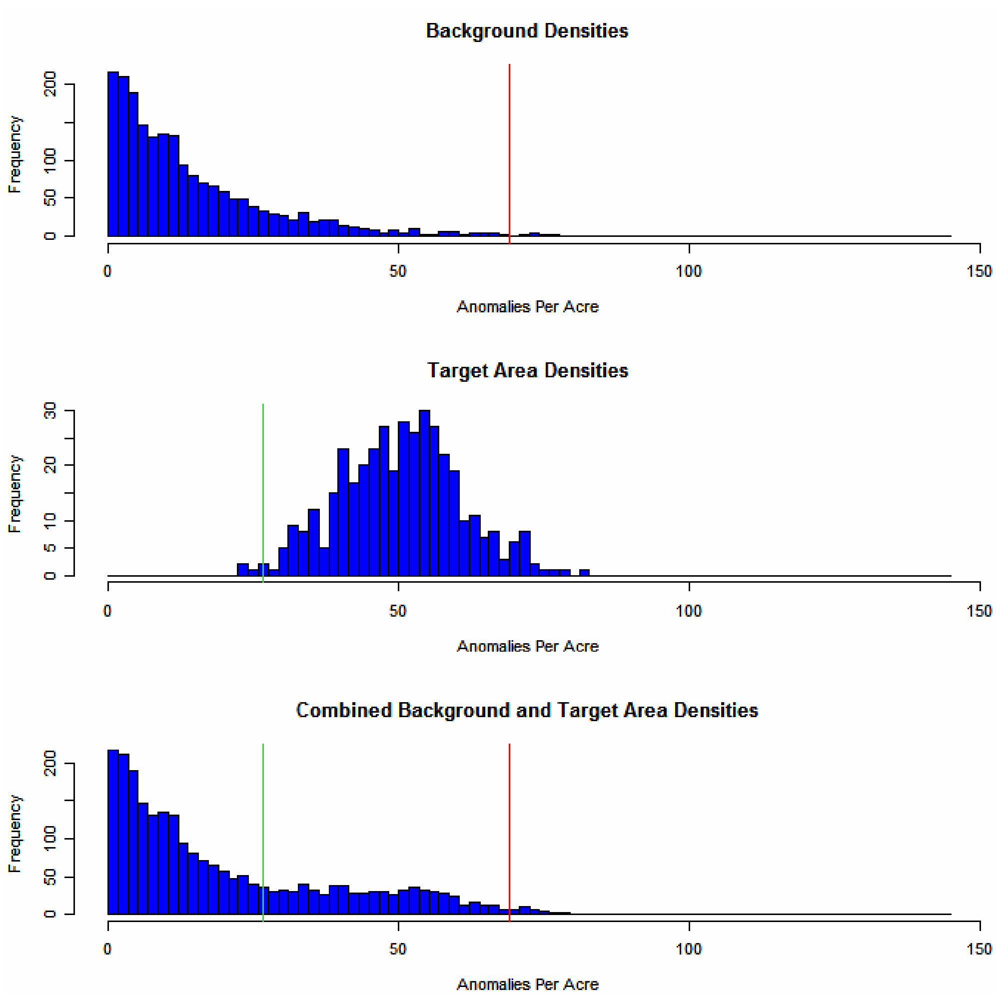


Figure 7.15. Distribution of Background Densities with Average Density of 15 ApA (anomalies per acre) and Standard Deviation of 15 ApA (top); (middle) Distribution of Target Area densities with Average Density of 50 ApA and Standard Deviation of 10 ApA; (bottom) Sample Distribution of Combined Density Distribution. The green line at 27 ApA is the point at which 99 percent of the target area densities are larger. The red line at 70 ApA is the point at which 99 percent of the background densities are smaller.

the distribution of densities in background areas on the site (areas not contained within a target area). The middle histogram shows the densities from a target area. The bottom histogram shows the combined densities from the first two. The bottom histogram is an example of a histogram produced in VSP when the location of the target area is unknown. The VSP user typically will have to try different combinations of parameters to get a feel for where possible target areas may lie and to get an idea of the site's possible background density.

7.3 Geostatistical Mapping of Anomaly Density

Within VSP, the geostatistical anomaly density mapping is composed of two primary tasks. The first task is to model the spatial variability of the measured anomaly densities as determined from the geophysical transect data. This task involves the development of a variogram based on the window-averaged transect density values. A variogram depicts how the variability of a set of values changes as the distance between the spatial locations of these values increases. The second task involves the estimation of anomaly density at unsampled locations within the study area through a geostatistical methodology know as kriging. Kriging uses the model of spatial variation as captured by the variogram to provide an unbiased, minimum-variance estimate of the anomaly density. Kriging is the procedure that creates the final anomaly density map. To use these methods, GAM/GAMV and KT3D also must be installed (see dqo.pnl.gov).

An anomaly density map can be created from the sample transect data by opening the "Geostatistical mapping of anomaly density" dialog (Figure 7.16). This dialog is opened by selecting "**Sampling Goals > Find UXO Target Areas > Geostatistical Mapping of Anomaly Density.**" This selection presents a menu with three screen tabs. The default tab, "Map Anomaly Density," presents several options for mapping anomaly densities. The second tab, "Variogram Model," provides an alternate means of accessing variogram fitting parameters once the variogram has been computed. The third tab, "Data Entry and Analysis," provides the ability to import files identifying the course over ground and anomalies as explained in Section 7.2.1.

There are two pathways to creating the anomaly density estimates. The basic pathway will create an estimate of anomaly density based on a series of default values computed from the current data set. The advanced pathway allows more control over the variogram and kriging parameters, but requires the user to possess a greater understanding of geostatistical analysis to be used in a meaningful manner. Each of these pathways is discussed below.

7.3.1 Basic Geostatistical Mapping

Under the default "Map Anomaly Density" tab of the "Geostatistical Mapping of Anomaly Density" dialog, the user is presented with two choices for computing the anomaly density map. In "Basic Mode," VSP will automatically compute a variogram and perform the kriging necessary to develop a spatial estimate of anomaly density. In this mode, a series of default values is computed for the data set and used in the variogram and kriging analyses. This mode is fully automatic and is the recommended path for new users to follow.

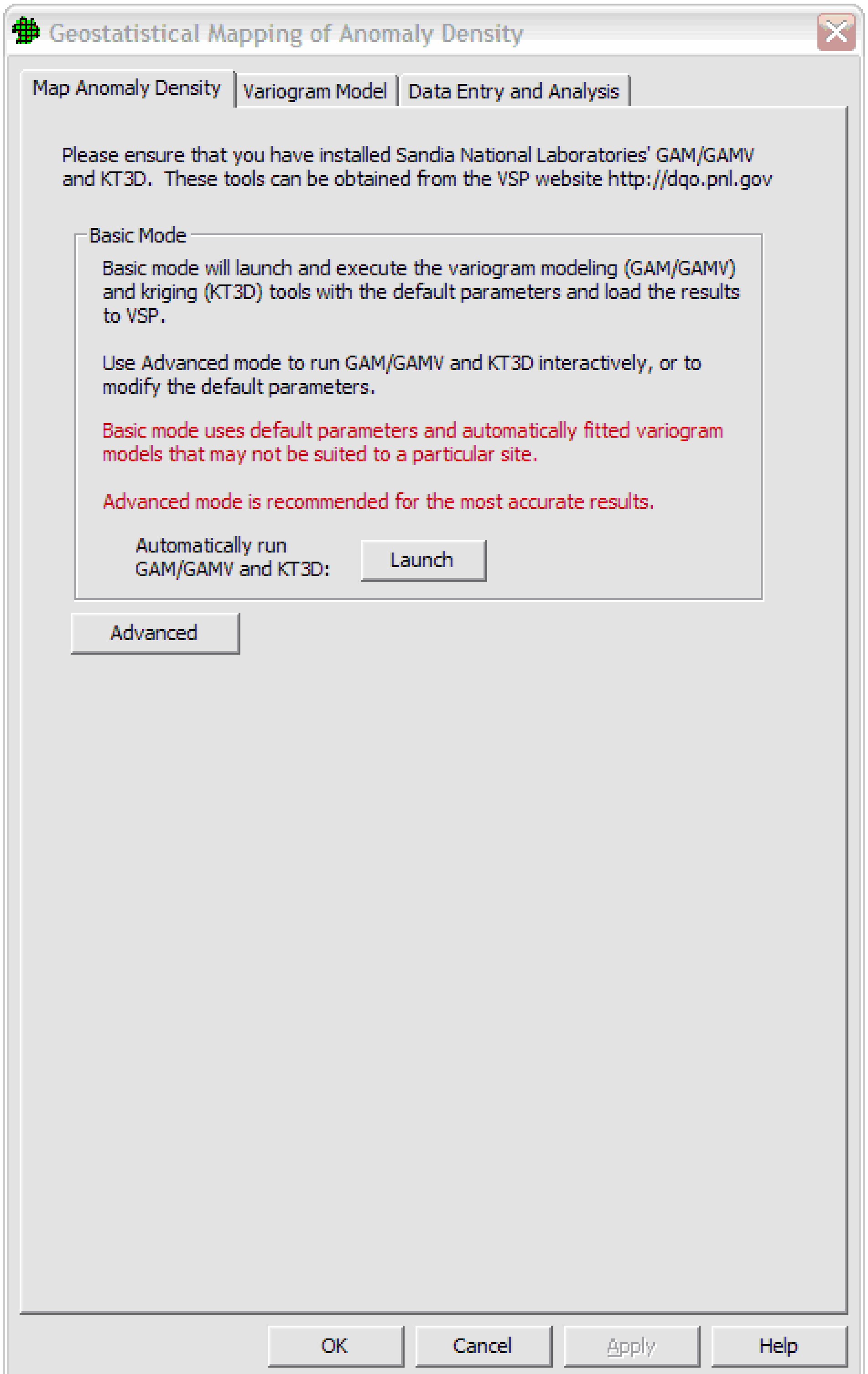


Figure 7.16. "Geostatistical Mapping of Anomaly Density" Dialog. This view shows the basic mode without the advanced operations screen box displayed.

To use the automatic mode, click on the “Launch” button within the “Basic Mode” screen box (Figure 7.16). Clicking on this button will launch a series of programs that will momentarily flash several operational windows to the screen before returning to the “Geostatistical Mapping of Anomaly Density” dialog. After successful completion of this process, the modeled variogram can be viewed by clicking on the “Variogram Model” tab in the “Geostatistical Mapping of Anomaly Density” dialog. Clicking on the “OK” button will close this dialog and load the anomaly density estimate map as an overlay onto the main VSP site map. At this point, the primary VSP mapping tools can be used to investigate the details of the estimated anomaly density map.

7.3.2 Advanced Mode Geostatistical Mapping

In the “Advanced” mode, the user is given complete control over all the parameter settings involved in the variogram and kriging analysis. This mode is recommended for experienced users or when specific analysis parameters are necessary.

Advanced mode is selected by clicking on the “Advanced” button under the “Map Anomaly Density” tab of the “Geostatistical Mapping of Anomaly Density” dialog. Clicking on this button will open a screen box with various selections for advanced mode operation (Figure 7.17). One parameter setting is directly available from this screen box. This is the averaging window diameter. This value specifies the size of the averaging window for computing the anomaly density values used in the geostatistical mapping. The variogram lag distance and kriging grid cell size also are affected by this parameter. The lag distance is the separation distance between pairs of data points. The lag distance collects the data pairs into groups based on separation distance and is discussed further below. The initial lag spacing and kriging grid cell size are set to be one-sixth the averaging window diameter by default. If an averaging window diameter other than the default value is desired, it should be changed before proceeding with the next steps in the analysis. The initial lag spacing and kriging grid cell size also can be changed by manually entering them using the advanced mode.

The first processing step in the “Advanced Mode” is to click on the button labeled “GAM/GAMV.” This selection will initiate the variogram calculation and then open a separate screen presenting a graphical interface for additional variogram analysis. At this point, the automatically fit variogram model can be viewed by clicking on the “Fitting” tab of the GAM/GAMV” screen (Figure 7.18). Here, the user will see the empirical variogram values as well as the automatically fit variogram model and its parameters (Figure 7.19). The variogram is computed from the averaged anomaly density values obtained from the geophysical survey transect data. The averaged anomaly densities are computed automatically using the averaging window diameter specified under the “Advanced Options” screen box, and the previously loaded anomaly locations and course over ground information. These values are then passed automatically to the GAM/GAMV code.

Various other tabs in the GAM/GAMV screen provide access to other variogram analysis parameters. Details regarding these other input parameters are given in GAM/GAMV interface code help files, and a full discussion can be found in Deutsch and Journel (1998). When running within the VSP environment, the data file and output file names should never be changed from their default values. In general, the only control parameters that might typically be altered at this stage in the analysis are the lag spacing, lag tolerance, and number of lags to compute. These parameters control how the observations for computing the empirical variogram are grouped and the maximum separation distance that should be considered. These parameters are discussed further below.

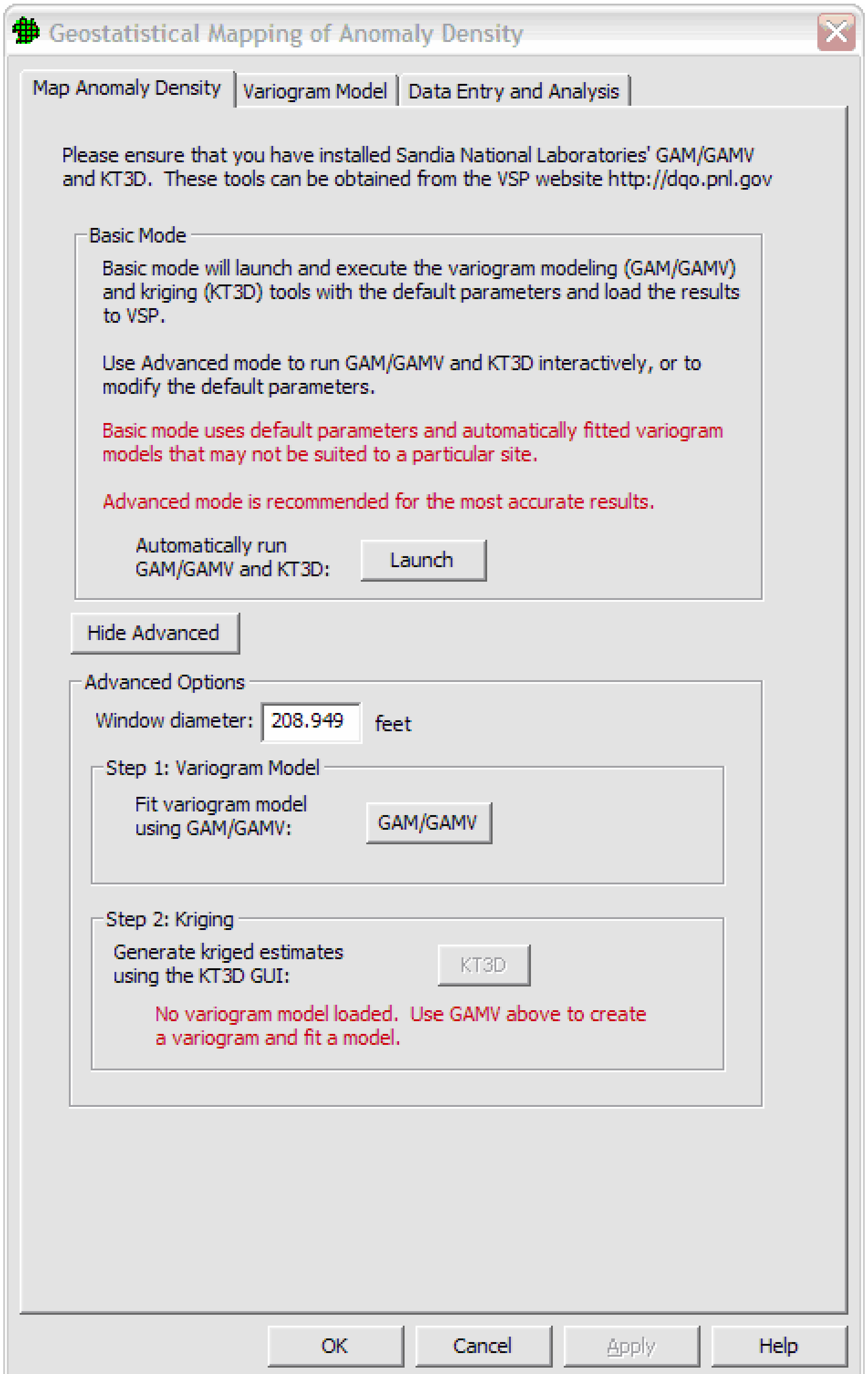


Figure 7.17. Advanced Mode for Geostatistical Anomaly Density Mapping

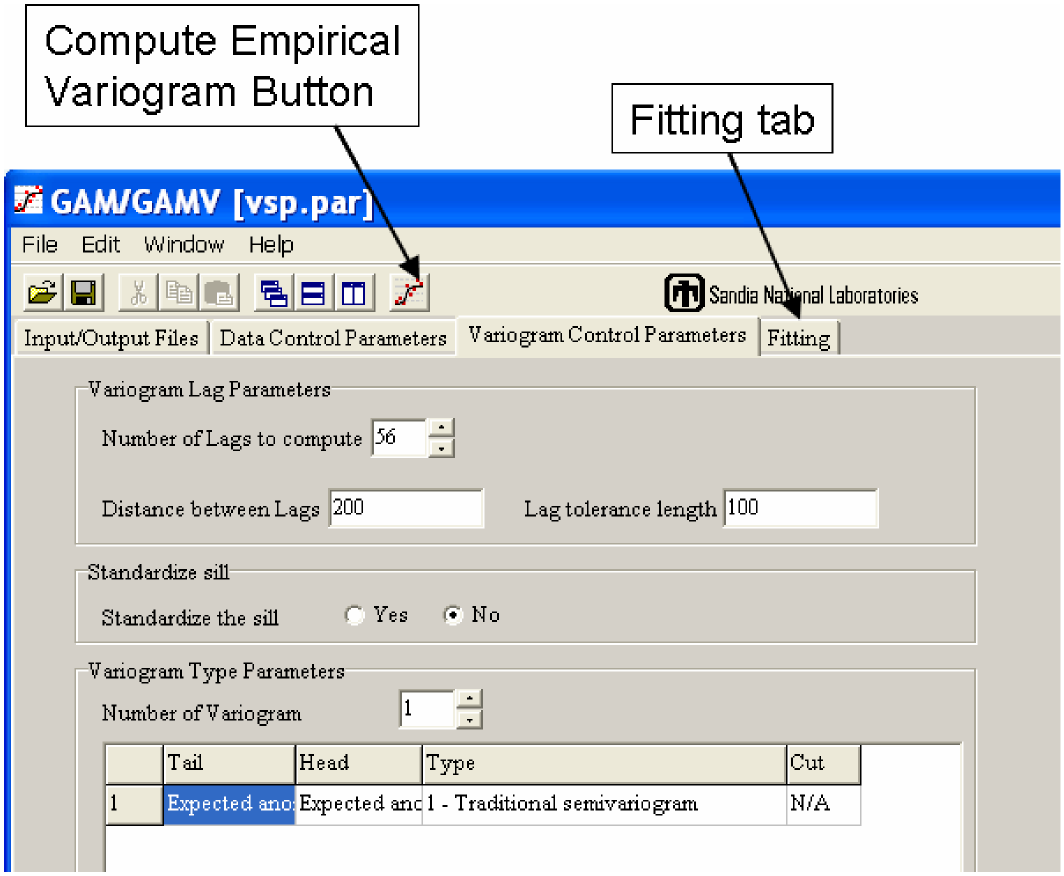


Figure 7.18. Aspects of the GAM/GAMV Interface Screen

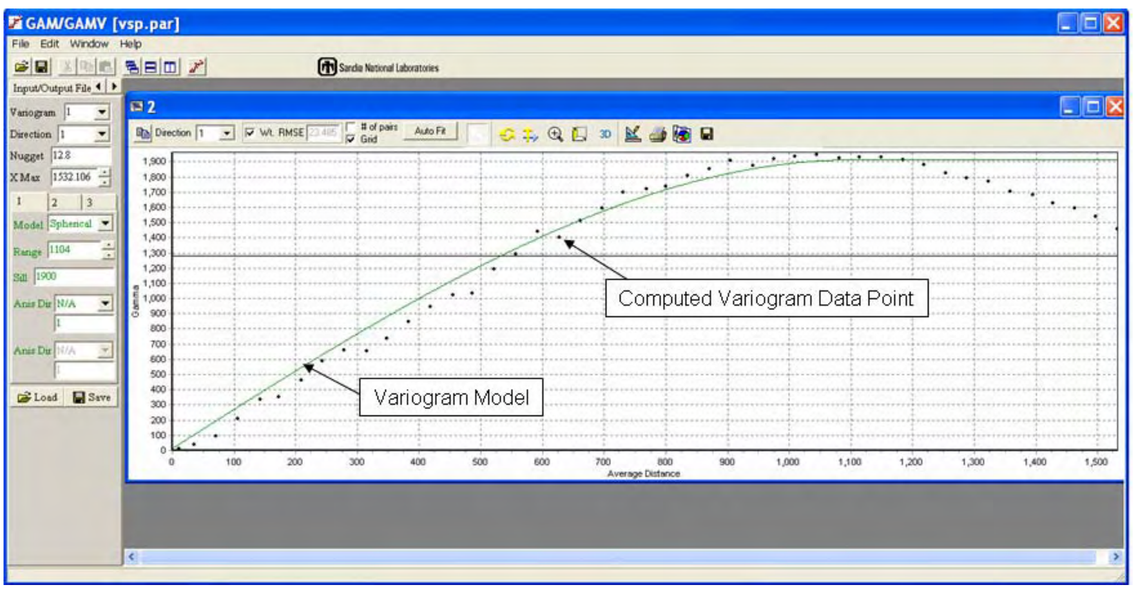


Figure 7.19. Variogram Fitting Screen from the GAM/GAMV Window. Dots show computed variogram values, and the solid green line shows the model fitted to variogram values. Parameters for this model are listed along the left side of the window.

The GAM/GAMV code is used to compute a variogram for the averaged anomaly density data. A variogram depicts how much the variation between pairs of sample values (anomaly density in the case here) changes as the distance between pairs increases. The lag distance—the separation distance between pairs of data points—is used to group the data pairs into groups based on separation distance. Then the "semi-variance" is computed for each group and plotted as part of the empirical variogram. Because most sample points will not be separated by exactly the specified lag distance, the lag tolerance is given to include those observations that are within the tolerance value of the specified lag distance. For example, using a lag distance and tolerance of 200 m and 100 m, respectively, will generate the following grouping of separation distances:

0 to 100 m	group 1
100 to 300 m	group 2
300 to 500 m	group 3

A semi-variance value for each group is then computed using all the data points with separation distances falling within the distance boundaries for that group. The separation distances are simply the straight-line distances between the sample pairs based on the sample point locations. The computed semi-variance values are then plotted along with the average separation distances for each group to create an empirical variogram (Figure 7.19). The empirical variogram is a graph showing one-half the average squared differences between all observations for a series of average lag distances.

The solid dots in Figure 7.19 show the computed experimental variogram values for specific lag distances. The X-axis shows the lag distance in length units (meters in this case), and the Y-axis shows the computed semi-variance value. In this example, the lag distance was 200 m and the lag tolerance was 100 m. The actual location of each data point on the X-axis is determined by the average actual lag distance of all the data pairs in that group. The solid green line shows the automatically fit variogram model for this data set.

One-half the average squared difference for all of the pairs of observations for each group will show up as a single data point on the experimental variogram. Within VSP, the along-transect data point spacing is controlled to be one-sixth the averaging window diameter; this is typically the minimum lag distance that should be used. This minimum value is a good place to start the variogram analysis and typically is sufficient for most studies. To include all data points and avoid overlap between variogram point groups, the lag tolerance should be set to one-half the lag distance. After any of the GAM/GAMV input parameters are changed, the variogram will need to be recomputed by clicking on the "Compute Empirical Variogram" button (Figure 7.18). This selection will recalculate the empirical variogram and display the results under the "Fitting" tab.

The "Fitting" tab of the GAM/GAMV window (Figure 7.18) interface will display the computed empirical variogram, and will also automatically compute an initial model to fit the data points. This model consists of a continuous function that closely matches the distribution of the empirical variogram data points. A continuous function that will produce a positive definite covariance matrix for solving the kriging equations is required as a model of spatial variability. Although a single model typically is sufficient, up to three different models can be nested simultaneously to provide a proper fit to the empirical data points. Excessive time should not be spent in creating a best-fit model of the empirical variogram data. Typically, the focus of the variogram model fitting should be on matching the experimental variogram points at the shortest lag spacings; the variance of the data set, shown by the solid horizontal black line, provides the theoretical maximum variogram value (see Figure 7.20). A reasonably good fit is usually sufficient when using sample transect data set.

The variogram model is reshaped by changing the range and sill values (Figure 7.20). The sill controls the height of the variogram model while the range controls the distance scale of the model. If a large initial jump in the variance is needed to match the empirical data, the nugget value can be increased. The nugget, sill, and range can be adjusted to match the computed variogram data points as needed. In addition, the basic model type (e.g., spherical, Gaussian, exponential) also can be changed as needed. The variogram model line will change dynamically as any of the modeling parameters are altered.

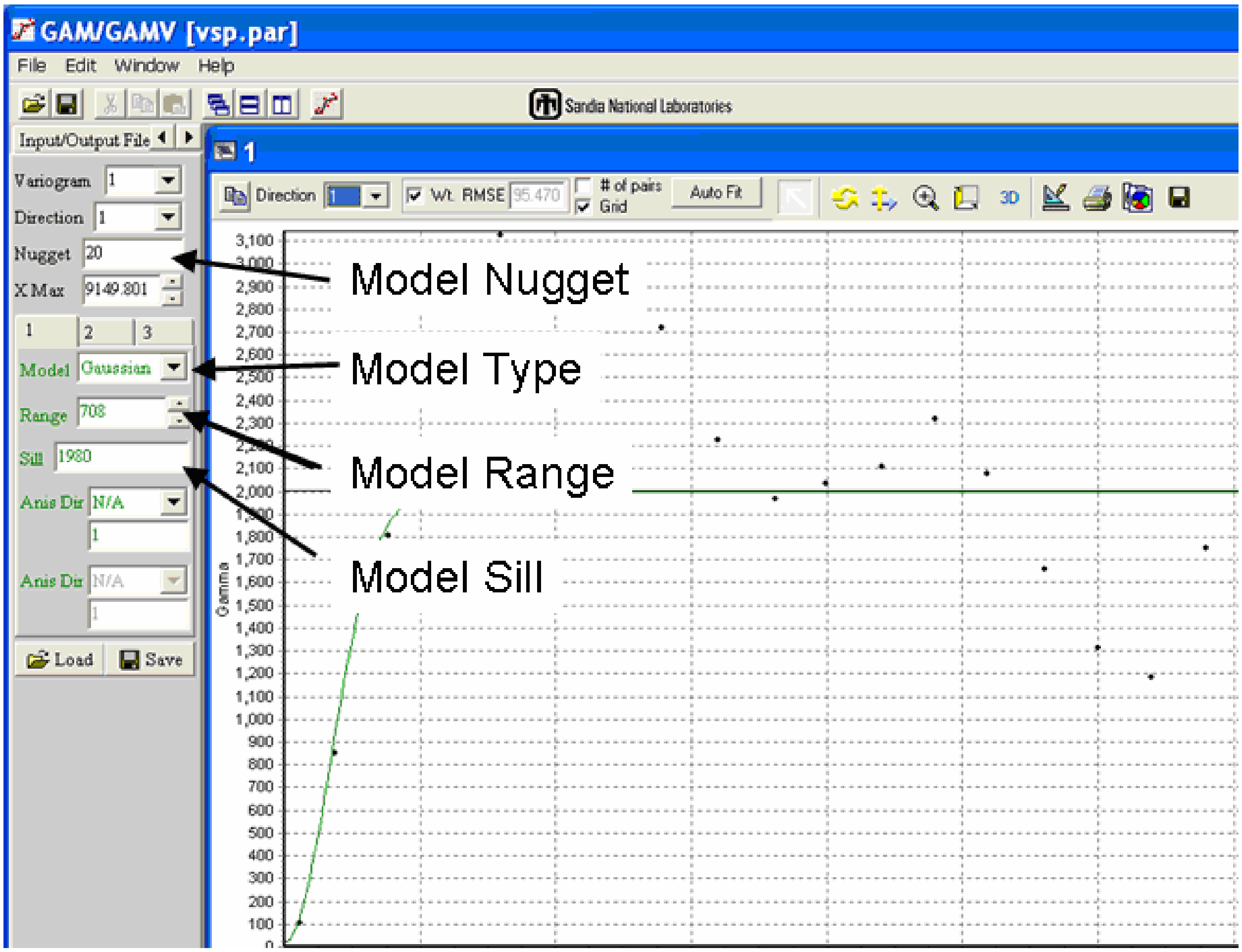


Figure 7.20. Variogram Model Parameters Settings Within the GAM/GAMV Graphical Interface

Figure 7.21 shows the effects of changing the range and sill values of the variogram model. The sample data for these plots were from a magnetometer survey of a portion of the Pueblo Precision Bombing Range in southeastern Colorado. The magnetometer transects from this survey were nominally spaced at 155 m and crossed two large high-density areas. As seen in these plots, the range and sill values can be adjusted until a sufficiently close match to the empirical data is made.

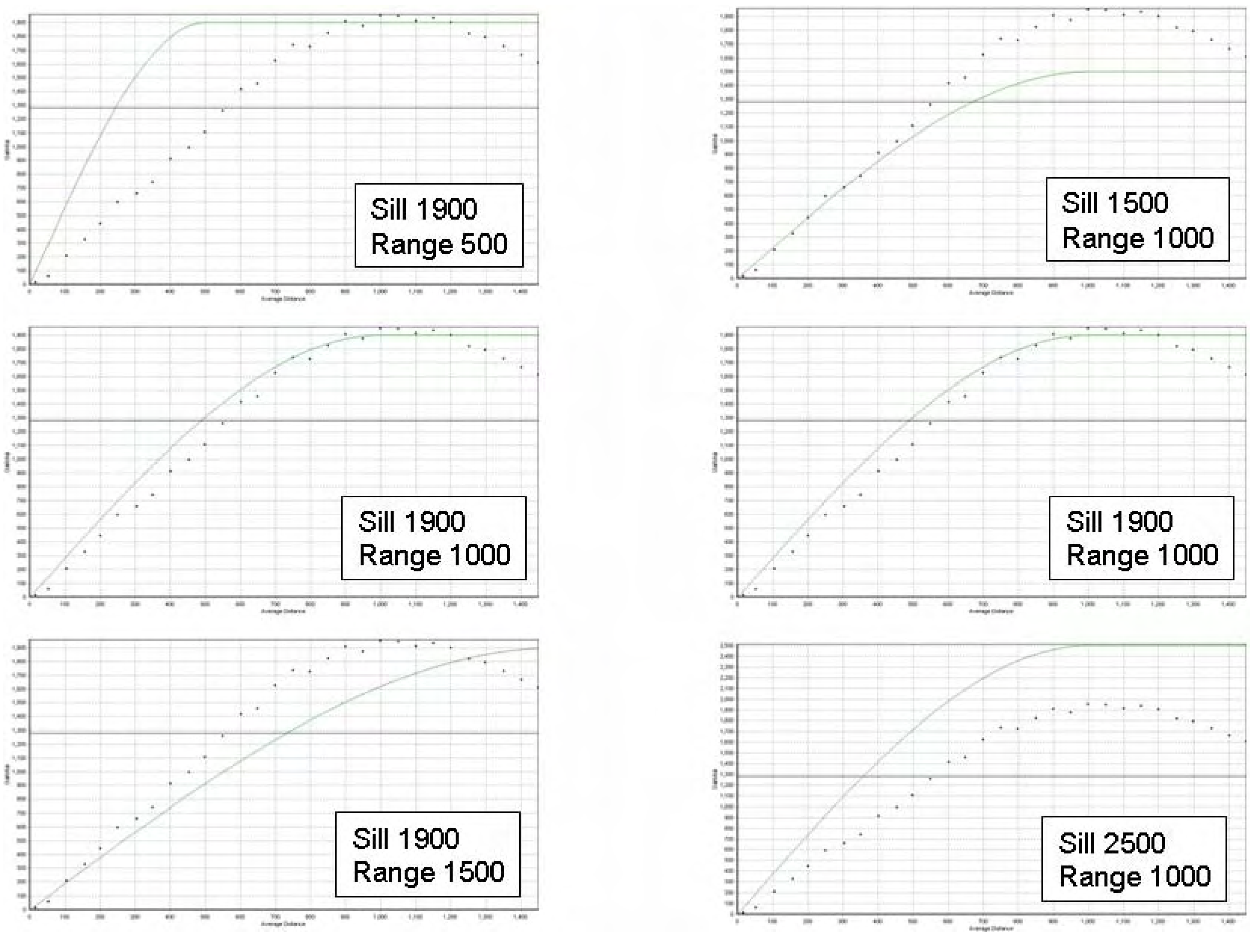


Figure 7.21. Effects of Changing Sill and Range Values for Variogram Model. Left column of plots shows effects of altering range value; right column shows effects of altering sill value. In each plot, dots represent empirical variogram values, and the green line shows model variogram.

Once the variogram model is fit satisfactorily, the GAM/GAMV interface can be closed. The next step is to create a map of the anomaly density across the site using the information in the variogram model. The spatial estimation tool is "KT3D." To begin, click on the KT3D button within the "Geostatistical Mapping of Anomaly Density" dialog. This will open the KT3D graphical user interface. The variogram model parameters developed using GAM/GAMV will be passed automatically to KT3D.

The KT3D interface provides full control of all parameters for the KT3D kriging code. A number of default parameters are already set, so the code can be run immediately by clicking on the "Run" button (Figure 7.22). This will generate a kriging estimate of anomaly density and display the results within the KT3D interface screen. To display the kriged estimate within VSP, simply close the KT3D interface screen, then click "OK" or "Apply" within the "Geostatistical Mapping of Anomaly Density" dialog box.

The other advanced options for running KT3D can be accessed through the various tabs under the main "Parameters" tab on the interface screen. A complete explanation of these various options is presented in the associated help files contained within the KT3D tool. When running within the VSP environment, the observation data file and kriging output file names should never be changed from their default values.

Figure 7.22. KT3D Interface Screen

The KT3D parameters most likely to be changed from their defaults are the gridding and search parameters. These parameters, which control the number, size, and extent of the estimation cells used to discretize the site and the search of local data to be used in the estimation of any location, respectively, are located under the "Grid" and "Search/Discretization" tabs. These parameters are explained fully in help files associated with the KT3D program, and a full discussion of the background of the estimation can be found in Deutsch and Journel (1998).

After all the parameters are set, the user clicks on the "Run" button to run KT3D. The kriging results are displayed automatically within the KT3D interface sub-window. In addition to the anomaly density estimate, the kriging variance is displayed in an adjacent window. Closing the KT3D interface window will return the user to VSP and the "Map Anomaly Density" dialog. Clicking on "OK" or "Apply" will display the kriging results in the VSP display.

7.3.3 Display of Kriging Results Within VSP

Whether run from "Basic" or "Advanced" mode, clicking on the "Apply" or "OK" button in the "Map Anomaly Density" screen will display the current kriging results within the VSP mapping window. The anomaly density map is displayed in VSP as a color-shaded value map. Figure 7.23 shows kriging results displayed in VSP. The anomaly density estimate in Figure 7.23 was developed from magnetometer surveys from a portion of the Pueblo Precision Bombing Range. The site is a World War II-era bombing range that shows evidence of two large target areas. The default color scheme in the map display shows the highest density values in red and the lowest values in green. A color scale is provided to aid in interpretation of the results. The lack of color shading (background color is displayed) indicates that no kriging estimation was performed for that location. This typically is the result of a lack of enough sample transect data within the search window for reliable estimates within that area. An example of this

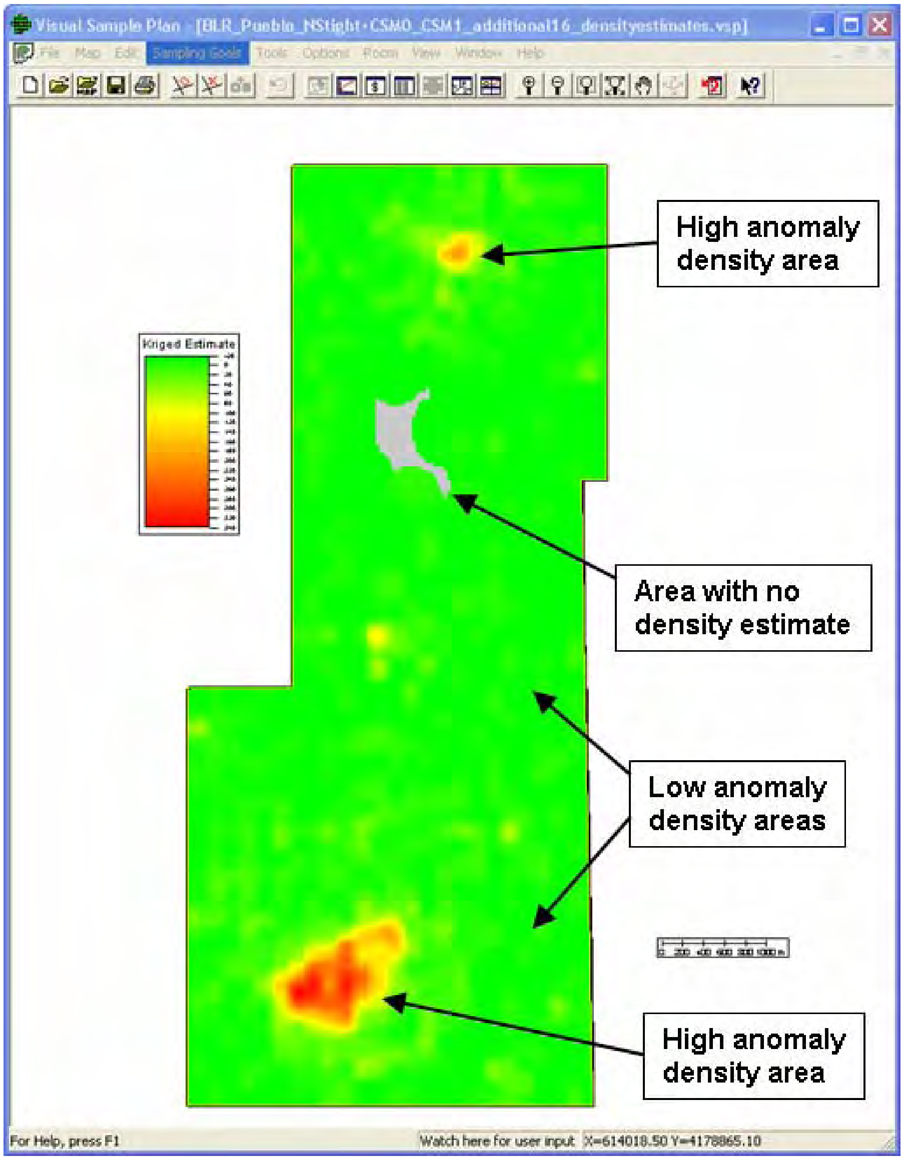


Figure 7.23. Results of Kriging Estimation Displayed in VSP

can be seen in Figure 7.24 as a gray area in the northern portion of the study area. Transects were not surveyed in this area because of vegetation and terrain issues. Because of this gap, no kriging estimates were developed for this area.

During examination of the anomaly density map, it is useful to turn on the display of the transect survey traces and the detected anomaly locations as aids in interpreting the anomaly density map (Figure 7.24). The controls for turning different map elements on and off are located under the "View" menu on the main VSP screen. This menu provides a listing of different mapping elements that can be checked on or off to control their display. The transect survey and detected anomaly locations provide a visual relationship between the kriging results and the support data used in the kriging analysis. For example, the transect traces shown in Figure 7.24 explain the gap in the kriging results in the northern portion of the Pueblo Precision Bombing Range study area.

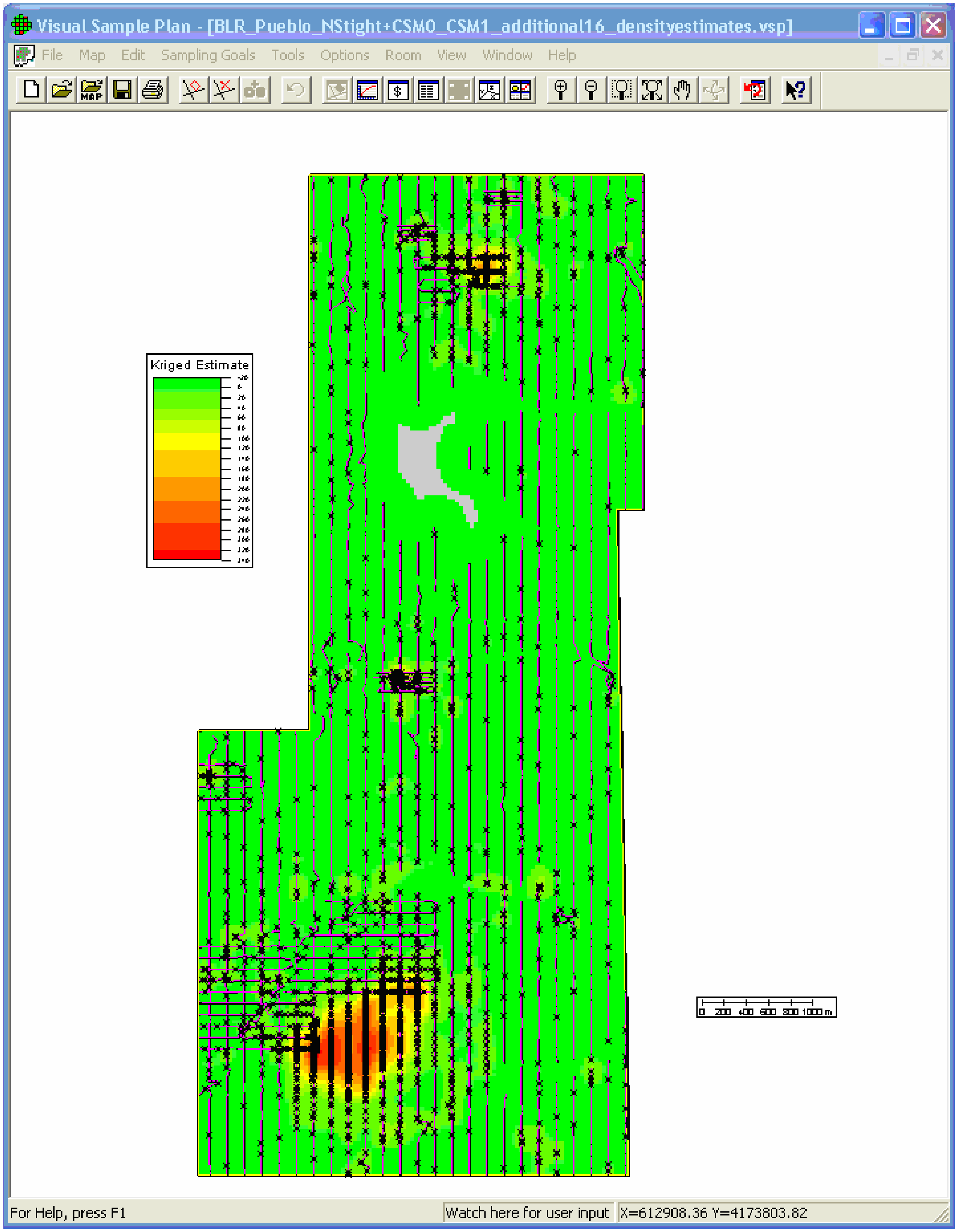


Figure 7.24. Results of Kriging Estimation Displayed in VSP Along with Course-over-Ground Traces and Anomaly Locations

The color scheme used for the anomaly density display can be changed by selecting the "View" pull-down menu on the main VSP screen, then choosing "Kriged Data" and selecting "Color Options." Various color palettes are available. Selecting one with a larger color range will bring out more details in the anomaly density estimate. Figure 7.25 shows the same anomaly density estimate for the Pueblo Precision Bombing Range as shown in Figure 7.23, but a different color palette (MBCGYOR-Grad) is used to enhance the variations in anomaly densities, thus bringing out some of the subtle details in the higher-density areas.

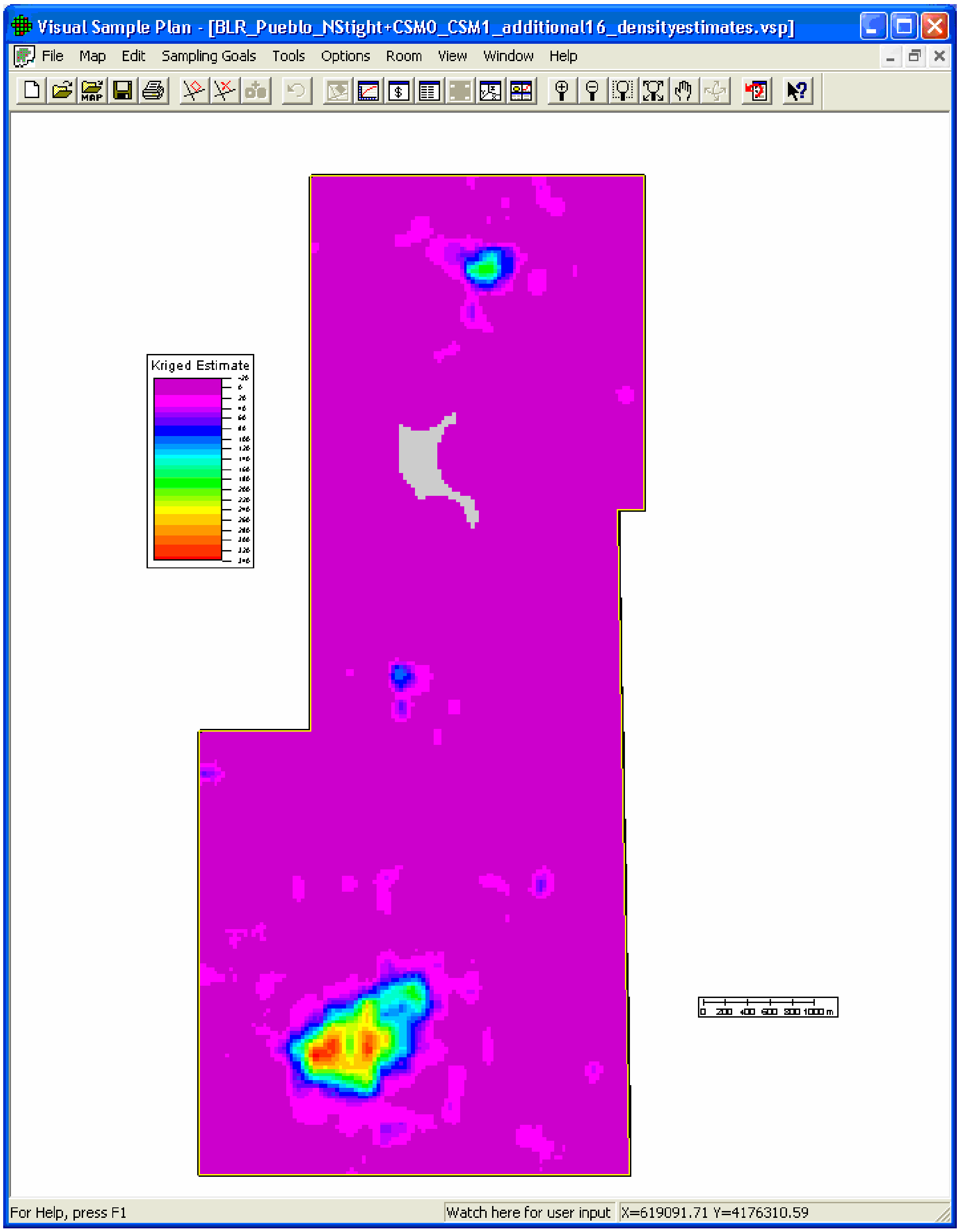


Figure 7.25. Kriging Results Displayed in VSP Using an Alternative Color Scheme

In addition to the estimate of anomaly density, the kriging procedure generates a map of the estimation variance. Figure 7.26 shows the kriging estimation variance computed for the kriging results from the Pueblo Precision Bombing Range study area. The estimation variance shows the uncertainty of the kriging estimate and is a function of the data configuration and the variogram model. Estimates of anomaly density for locations on or near sample transects should be very accurate and, hence, have a low uncertainty. Conversely, estimates distant from the sample transects are likely to be less accurate with a relatively high uncertainty. The value of the estimation variance reaches a maximum at distances greater than or equal to the variogram range away from the nearest data point. The map of estimation variance shows how the variance of the anomaly density changes across the study site. In Figure 7.26, the highest variance values are shown in shades of red; the lowest values in shades of green. The highest variance values occur in the northern portion of the site where there is a large gap in the sample transects because of terrain and vegetation issues. The maximum variances occur on the edge of the region where no estimates could be made. These high variance values indicate that some areas exist within the site where there are enough nearby data points to create a kriging estimate, but the uncertainty in these estimates is large. While not explored further here, the kriging variance provides a means of identifying regions of high uncertainty and can be used to design additional transect surveys. The lowest variance values are found at the survey transect locations.

The anomaly density estimates can be exported to a file format that is compatible with the ESRI ArcGIS geographic information software system. This is done by selecting "**Map > Map Layers > Export**" from the main VSP screen. This will provide options for exporting the current kriging estimates or the kriging variances. Maintaining the filename extension of "ASC" will provide direct recognition of the export file within ArcGIS. This export file format can be read directly into ArcGIS.

To view the estimation variance, select the "View" pull-down menu on the main VSP screen, then choose "Kriged Data" and select "Kriging Variance." As shown in Figure 7.26, there is a strong relationship between the sample transect locations and the kriging variance. The variance is low closest to the transects and increases with increasing distance from the sample locations. This can be used as a quick check to confirm that all the appropriate sample data have been included in the kriging analysis and to identify areas where the confidence in the kriging results could be increased with additional sample data.

7.3.4 Delineating High-Density Areas

As seen in Figure 7.23, there appear to be two main high anomaly density areas at the Pueblo Precision Bombing Range, one in the northern part of the site and a larger area in the south. The anomaly concentration, transect coverage, and kriging variance (Figure 7.24 and Figure 7.27) confirm that these areas are well sampled and contain a large number of magnetic anomalies. At this point, the anomaly density estimate map can be used as a tool to identify those high-density areas that are probable former target locations.

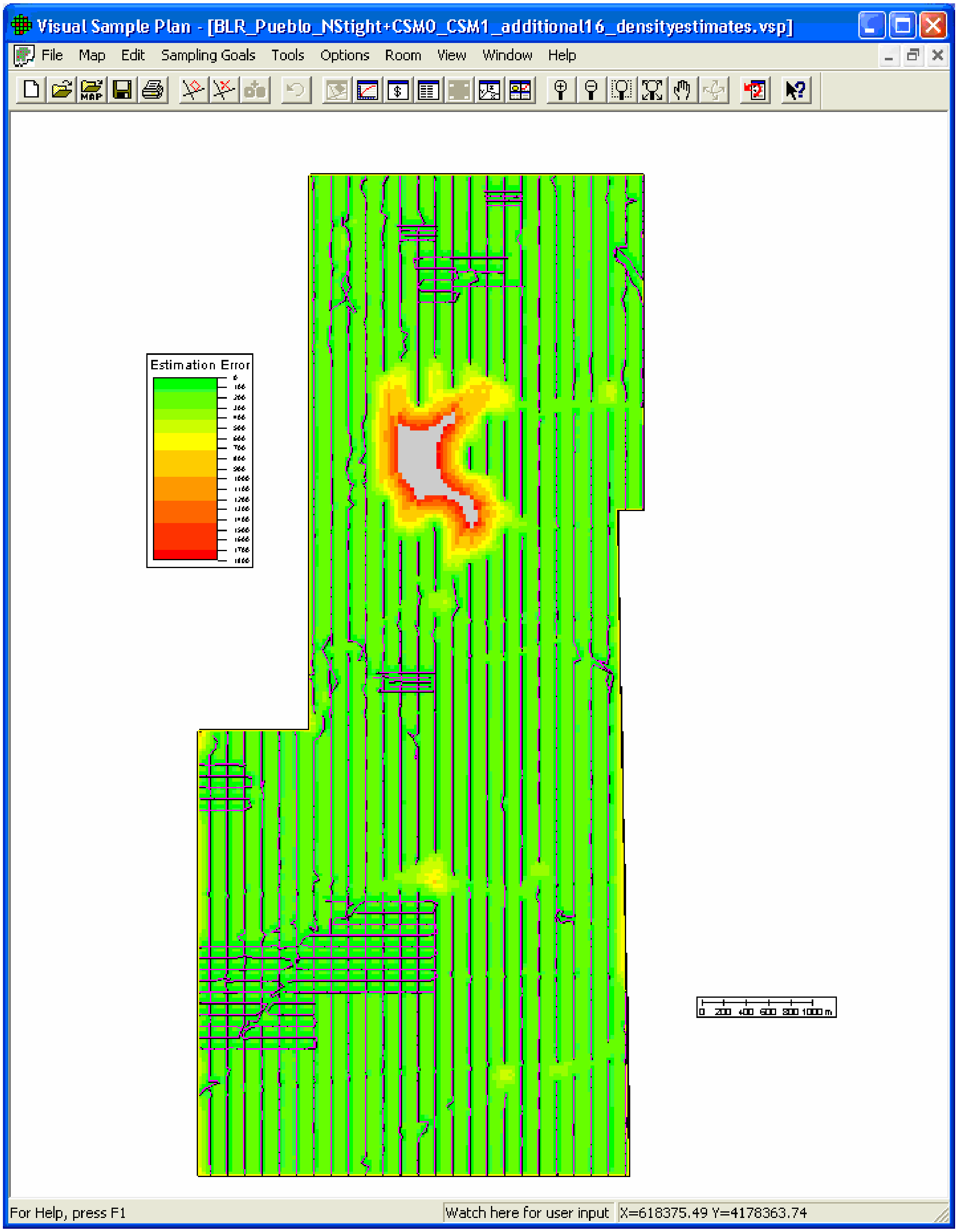


Figure 7.26. Kriging Variance Displayed in VSP Along with Course-over-Ground Traces. The highest variance values are shown in red, the lowest values in green.

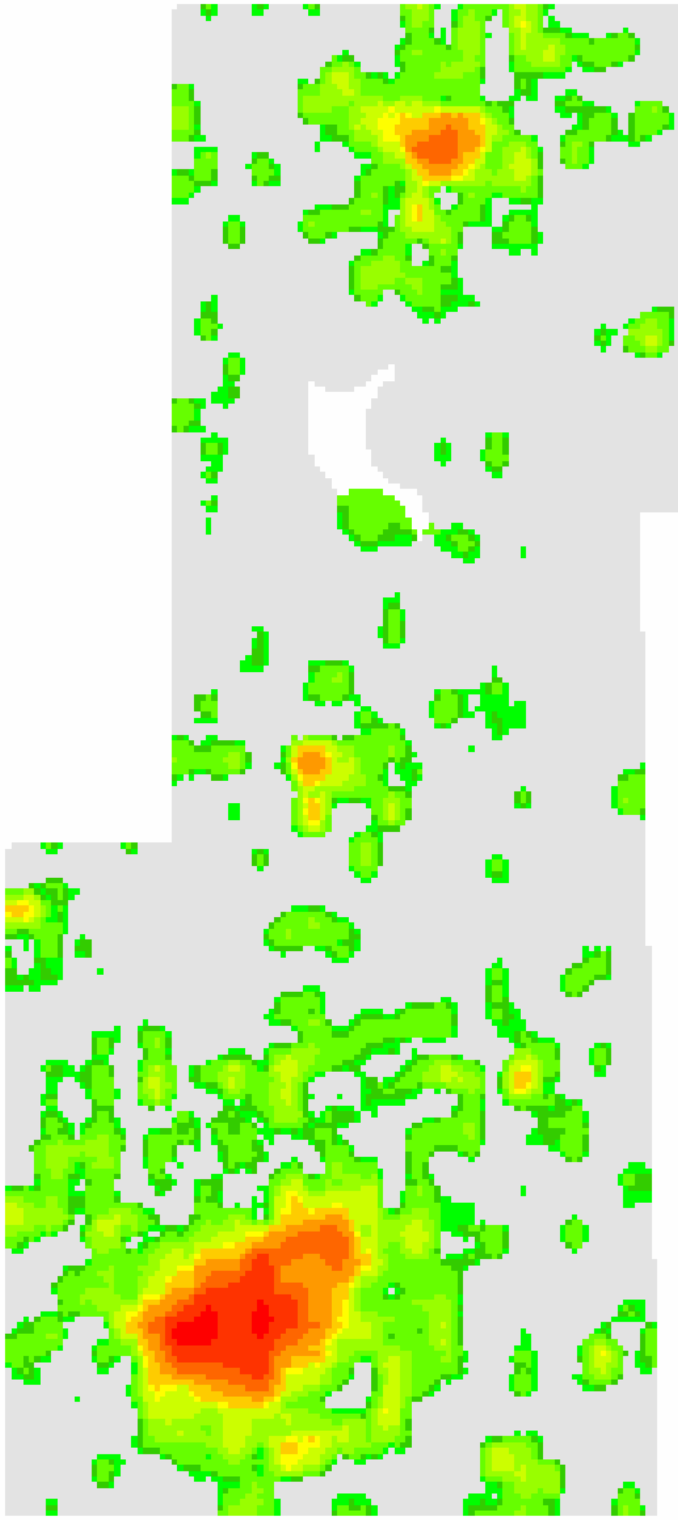


Figure 7.27. Anomaly Density Display for the Pueblo Precision Bombing Range WAA Site Resulting from Selection of a Too-Low Critical Density Cutoff Level. Areas of highest anomaly density are shown in red; lowest-density areas are shown in green. Gray indicates areas in which the anomaly density is below the critical density.

The initial step in target area delineation is to focus the kriging anomaly density estimate so that only high-density locations are displayed. The results from this process are very similar to those obtained from the density flagging routine and displayed in the resulting histogram (see Section 7.2.2). The goal is to adjust the color range for displaying the kriging results so that only those high-density areas that are likely target locations are displayed. This provides an interactive analysis technique that gives rapid feedback on the spatial extent of potential target areas. This process can be performed within VSP, or the kriging estimates can be exported and brought into ArcGIS for this analysis.

To change the kriging display within VSP, go to "**View > Kriged Data > Color Options**." The dialog box presented will allow the user to change the minimum and maximum display values. Changing the minimum display value to a value considered to be slightly above background will change the kriging data display to show only those values above the selected minimum. Changing the minimum display density is similar to setting the critical density in the VSP flagging routine (Section 7.2.2). Review of the spatial distribution of the kriging display will lead to refinement in this critical density value (see below). This interactive technique is iterative, thus allowing different critical density cutoff values to be investigated. A more automated technique is currently under development for inclusion into VSP.

To perform the critical density analysis within ArcGIS, first export the kriged density estimate data (see Section 7.3.3) to an ASCII file, and then import this file into ArcGIS. Once imported, the anomaly density data will be displayed as a color-shaded grid similar to that used in VSP. At this point, the display properties can be altered in a fashion similar to that used in VSP to control the critical density cutoff level. This alteration process requires some familiarity with ArcGIS and how to control the symbology of the displayed layers.

Regardless of which technique is used, the identification of targets using critical density cutoff levels is similar. The process of investigation of different cutoff levels is shown in Figure 7.27 through Figure 7.29. Figure 7.27 shows the anomaly density display resulting from using a critical density level that is too low to allow accurate delineation of specific target areas. In Figure 7.27, several compact high-density areas (shown in red) are displayed, but they are surrounded by halos of irregularly shaped low-density areas (shown in green). The irregular shape and discontinuous nature of these green areas indicates that they more likely related to the background anomaly distribution at the site rather than to any concentrated munitions use that would be expected for a target area.

Figure 7.28 shows the anomaly density display resulting from using a critical density level that is too high to provide assurance that all the major target areas have been identified. Several of the original compact higher-density areas have been dropped from the display, including the high-density area in the northern portion of the study area. In addition, the size of the high-density area in the southern part of the Pueblo Precision Bombing Range site has been dramatically reduced in Figure 7.28.

Figure 7.29 shows the anomaly density display resulting from a more appropriate choice of anomaly density cutoff level. The highest-density areas are represented by continuous compact features (shades of yellow and red) that do not have excessive fingering around their perimeters. Several large high-density areas can be readily identified as likely target areas. Additional smaller, low-density areas are also present, but the history of this site (i.e., an aerial bombing range) suggests that these areas are too small in scale to be considered as likely target areas. With the exception of the small, isolated low-density areas, the areas shown in Figure 7.29 can be used as boundaries for delineating likely target areas.

Figure 7.28. Anomaly Density Display for the Pueblo Precision Bombing Range WAA Site Resulting from Selection of a Too-High Critical Density Cutoff Level. Areas of highest anomaly density are shown in red; the lowest-density areas are shown in green. Gray indicates areas in which the anomaly density is below the critical density.

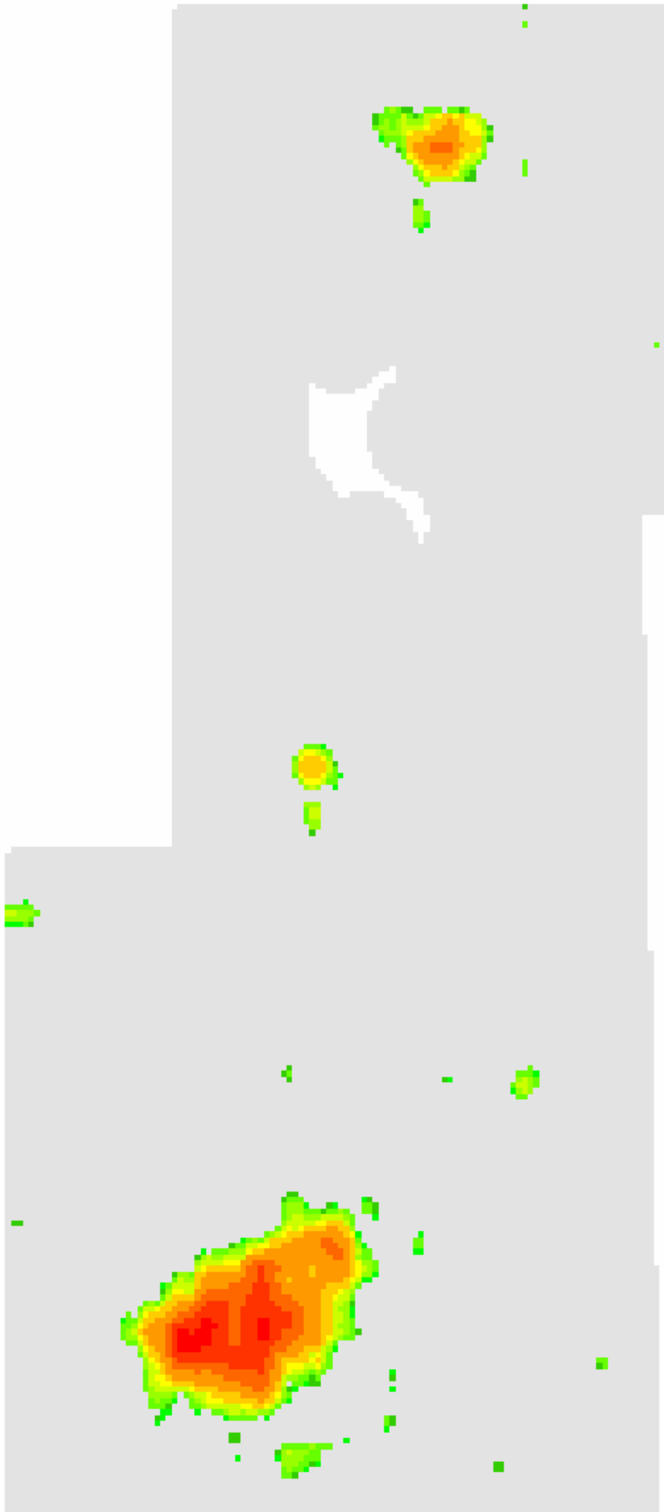


Figure 7.29. Anomaly Density Display for the Pueblo Precision Bombing Range WAA Site Resulting from Selection of an Appropriate Critical Density Cutoff Level. Areas of highest anomaly density are shown in red; green indicates lowest-density areas. Gray indicates areas in which the anomaly density is below the critical density.

7.4 Assess Probability of Target Traversal Based on Actual Transect Pattern

By selecting **Sampling Goals > Find UXO Target Areas > Assess probability of target area traversal based on actual transect pattern**, the user can apply the actual transect pattern applied at a site and determine the probability that a target area of a specified size would be traversed by this pattern if the target were located randomly. This transect pattern application is done by a Monte Carlo simulation in which each iteration randomly places the specified target area and determines if any transects traverse it. The "Post-Survey Probability of Traversal" dialog shown in Figure 7.30 uses the COG data to identify any locations on a site where a target area of the shape defined in the "Target Zone" tab could be located and not traversed. The number of iterations to run is set by the *Number of Trials*. The map in Figure 7.31 shows points (marked with a red "x") where a target area of the size specified on the target zone tab could be located and not traversed. As the "Traversal Simulation" tab in Figure 7.30 shows, the transects within this area had an 82 percent probability of traversing all possible 500-ft-diameter target areas.

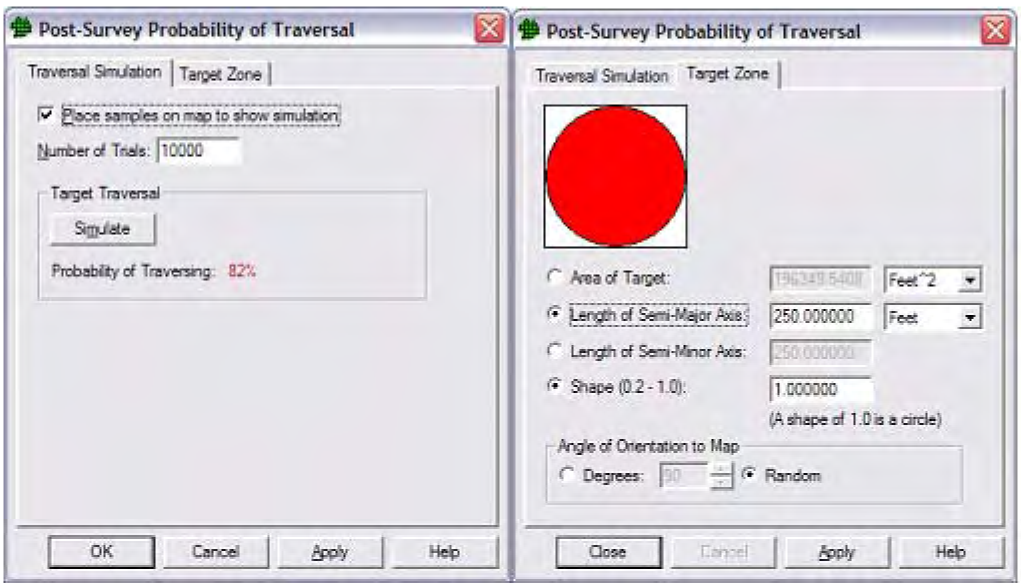


Figure 7.30. "Post-Survey Probability of Traversal" Dialog Used To Assess the Probability of Traversal Based on the Actual Transect Survey. This dialog has the "Detection Simulation" tab (left) and the "Target Zone" tab (right).

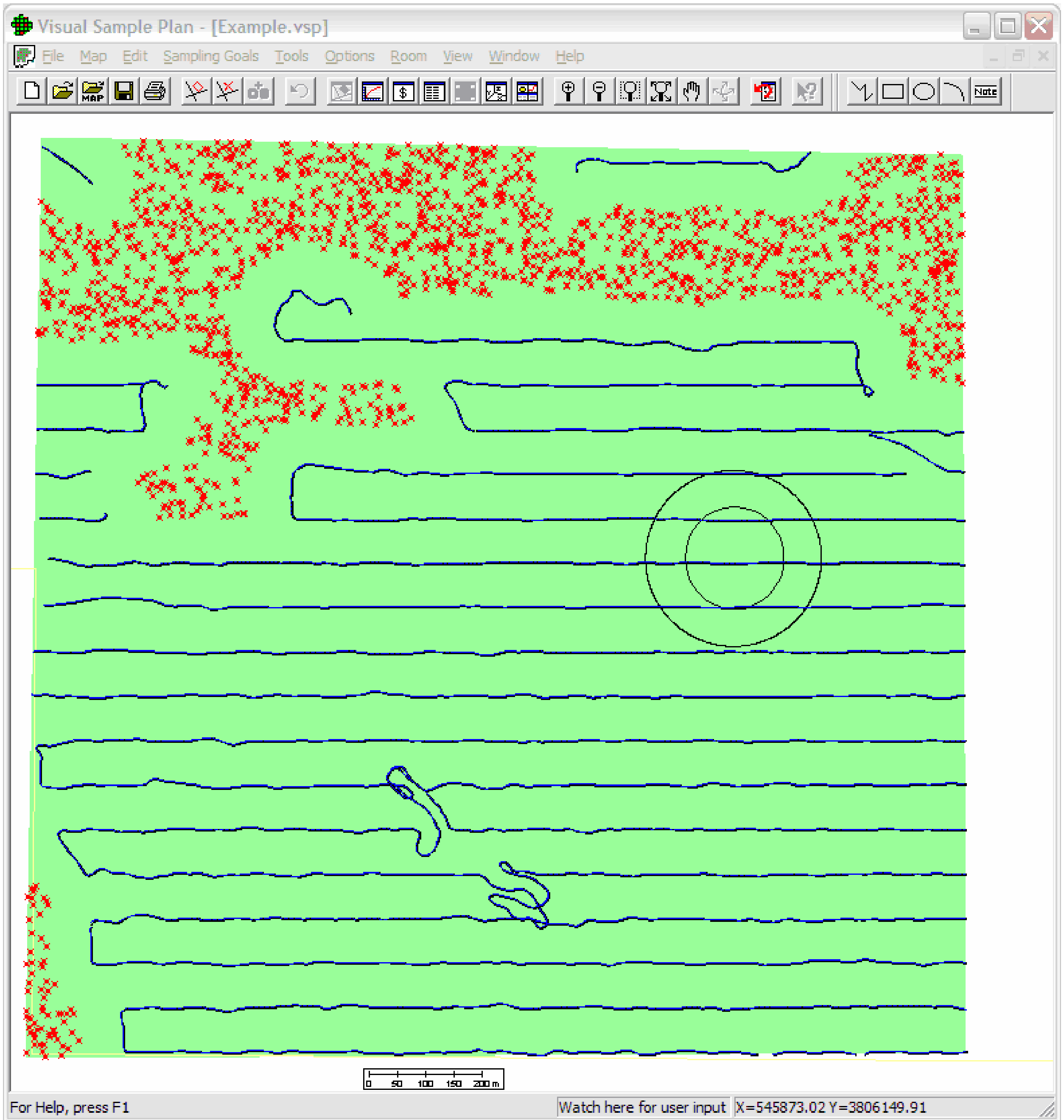


Figure 7.31. Example of the Map View After Clicking on the “Simulate” Button on the “Detection Simulation” Tab of the “Post-Survey Probability of Traversal” Dialog

7.5 Assess Degree of Confidence in UXO Presence

The UXO modules in VSP for assessing the degree of confidence in UXO presence assist in developing a sampling strategy to achieve high confidence that very few UXO are present at a site or that very few detected anomalies at a site are UXO. The module can be used to determine the number of transects that should be surveyed to establish Y% confidence that at least X% of the transects at the site do not contain UXO, where Y, X, and the number of transects are entered by the user. The same method can be applied to detected anomalies to determine the number of detected anomalies to dig up to establish Y% confidence that at least X% of the detected anomalies are are not UXO.

In the Sampling Goal covered in this section, if there are UXO, they are *single*, *isolated* objects not in any particular pattern. Two scenarios of interest are 1) a small UXO-remediated area where a survey is required to support a no-further-action (NFA) decision and 2) a very large unremediated area not expected to contain any UXO. In both scenarios, we assume the area of interest has a well-defined boundary. The area is divided into N non-overlapping, parallel transects with transect width equal to the width of the geophysical survey equipment. If N is large and only n of these transects can be surveyed, how should n be determined? This is similar to a compliance sampling problem in an industrial quality control setting where the goal is to determine if there are any defects before releasing a product.

VSP addresses the variant of the problem where n must be of sufficient size to achieve a high confidence that few transects contain UXO. The method can also be applied to anomalies detected during a survey to achieve a high confidence that few detected anomalies are UXO.

7.5.1 Achieve High Confidence That Few Transects Contain UXO

Menu selection **Sampling Goals > Assess Degree of Confidence in UXO Presence > Achieve high confidence few transects contain UXO** brings up the dialog box in Figure 7.32. Using this rectangular area we enter a transect width of **1 ft**. VSP informs us that there are N = **64** total nonoverlapping transects within this Sample Area. The 64 transects are shown in yellow and pink in Figure 7.32. The VSP user enters **90%** as the minimum number of transects required to not contain one or more UXO (DQO input) and **90%** as the confidence that this maximum percentage is not exceeded. VSP calculates that **19** of the 64 transects must be selected, using simple random sampling, and none of these transects can contain UXO in order to be "90% confident that at least 90% of the possible transects at the site do not contain UXO. The n =19 randomly selected transects that VSP placed on the Map when the Apply button is pushed are the pink transects shown in Figure 7.32. Attribute Compliance Sampling (ACS) (Schilling 1978; 1983, pages 475-482) is a statistical approach for establishing confidence in the cleanup effort. The sample size equation programmed into VSP for this problem is a method from Bowen and Bennett (1988). For extensive discussion of this problem and compliance sampling methods, consult VSP **Help** or Gilbert et al. (2003, Chapter 6).

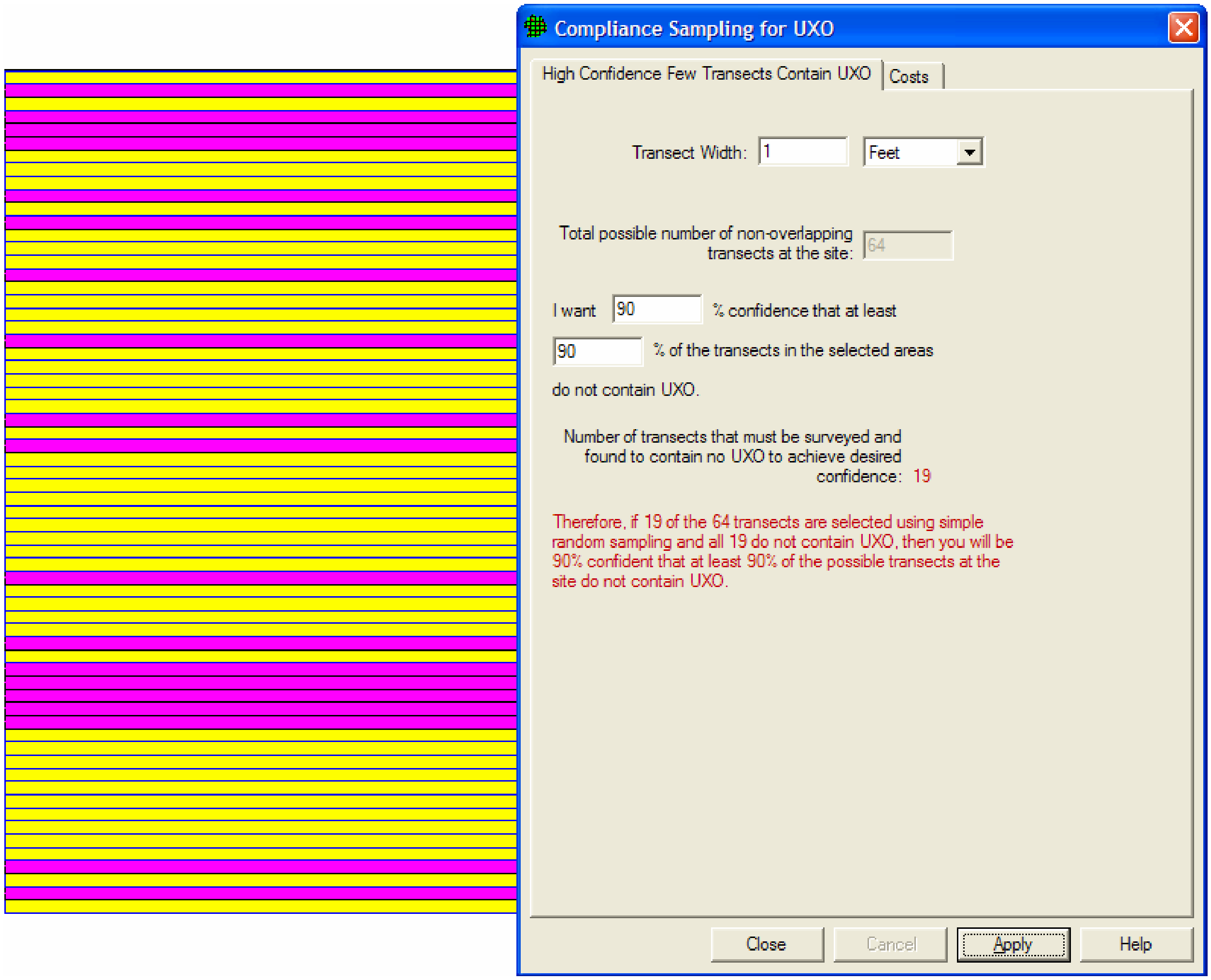


Figure 7.32. Dialog Input Box for Compliance Sampling for UXO and Map of Sample Area with Transects Selected

7.5.2 Achieve High Confidence That Few Anomalies are UXO

Menu selection **Sampling Goals > Assess Degree of Confidence in UXO Presence > Achieve high confidence few anomalies are UXO** brings up the dialog box in Figure 7.33. Using the Millsite.dxf map and the large elliptical area selected as our Sample Area, we now include some data on anomaly locations. The 137 anomalies are shown either as small black "x" or small pink circles in Figure 7.33. The VSP user enters **90%** as the minimum number of anomalies required to not be UXO and **90%** as the confidence that this maximum percentage is not exceeded.

VSP calculates that **39** of the 137 anomalies must be selected, using simple random sampling, and none of these anomalies can be UXO in order to be "90% confident that at least 90% of the possible anomalies at the site are not UXO. The *n* = 39 randomly selected anomalies are shown on the map as small pink circles when the Apply button is pushed, as shown in Figure 7.32. The sample size equation programmed into VSP for this problem is a method from Bowen and Bennett (1988).

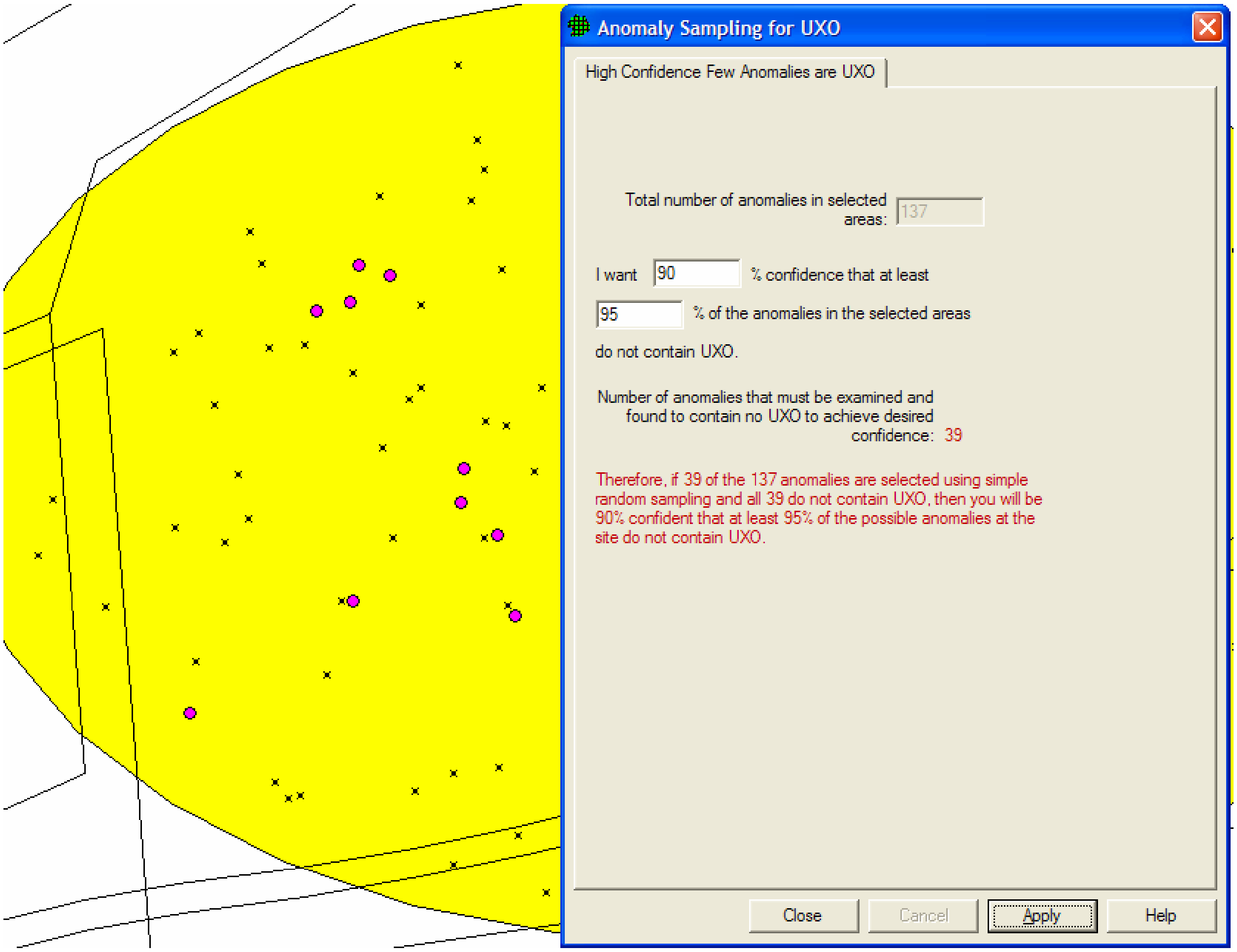


Figure 7.33. Dialog Input Box for Anomaly Sampling for UXO and Map of Sample Area with Anomalies Selected

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